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Soil
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Service

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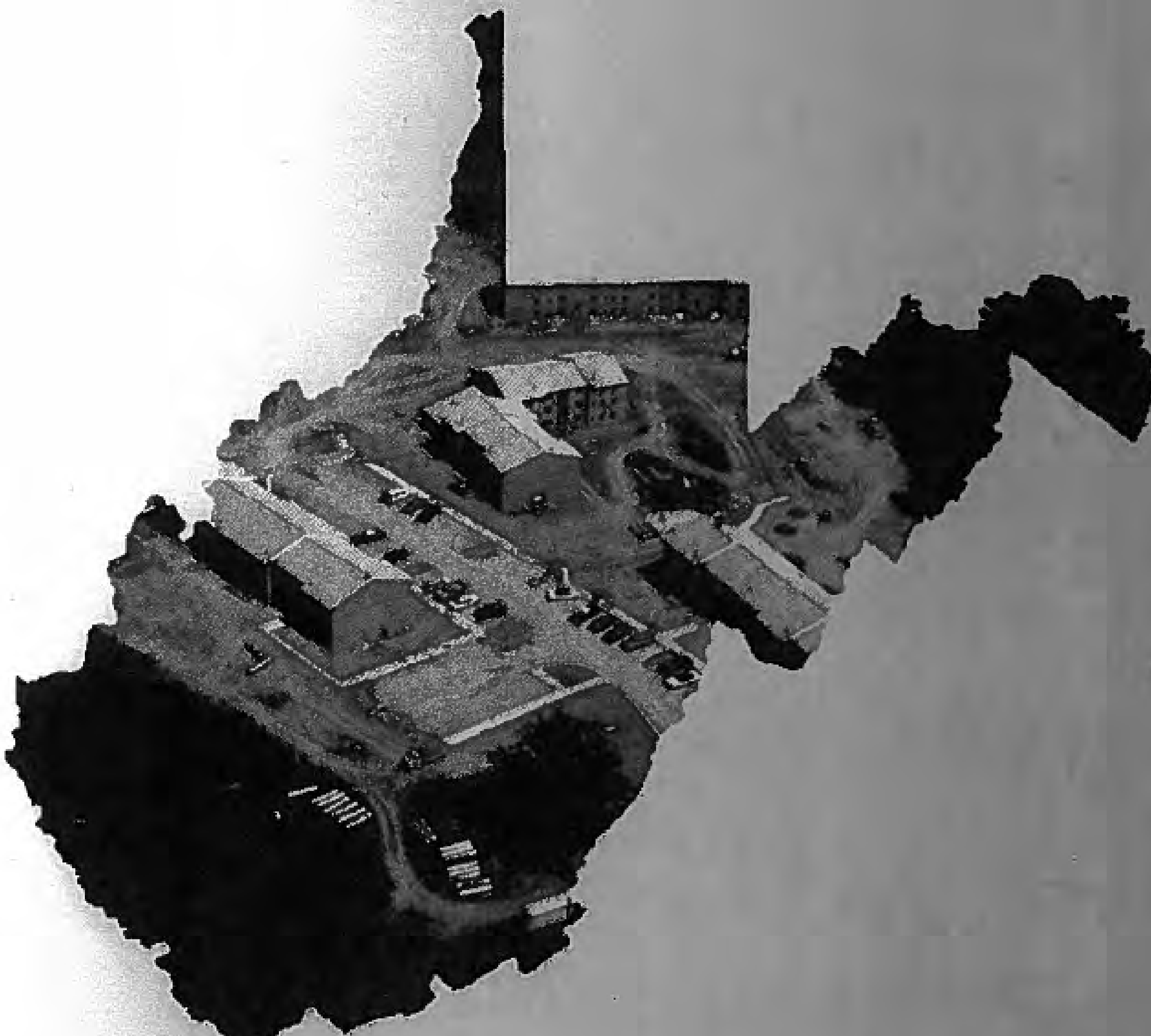
West Virginia
Erosion and Sediment Control Handbook for Developing Areas



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Introduction

Soil erosion has occurred in what is now West Virginia since the beginning of time. Prior to discovery and settlement, erosion was at a slow rate and a part of the natural geologic process. Nearly all of the land was covered by forests, which protected the soil under layers of leaf litter.

With settlement came the need to live on and make income from the land. From time to time and place to place, people removed protective coverings which in the natural state ranged from trees and shrubs to grasses. This allowed rainfall and runoff to erode the soil at a faster rate.

In recent years, land use in West Virginia has changed quickly and significantly around many of the towns and cities. More land has been used for developmental purposes, including housing. An undesirable result has been accelerated erosion. Also undergoing erosion and contributing to stream sedimentation has been land disturbed by other land-use activities such as agriculture, road building, utility construction, and coal mining.

The first purpose of this handbook is to make people aware—especially those persons helping plan and make land-use decisions—of how erosion will accelerate at construction sites. The second purpose is to provide guidelines for reducing the erosion and to suggest the means and methods for controlling erosion.

The West Virginia State Soil Conservation Committee has been designated as the management agency for implementing agriculture and construction components of the non-point source management program in West Virginia. This program was approved for implementation by the Environmental Protection Agency in December of 1989. Since that time, the program has been implemented by placing technicians at the local Soil Conservation District level to assist land users in developing erosion and sediment control plans for agriculture and construction activities. This assistance will be provided in the form of review, comment, and approval of sediment and erosion control plans and storm water management plans for urbanizing areas, developers, contractors, and municipalities.

As Chairman of West Virginia State Soil Conservation Committee, I am pleased to present this Erosion and Sediment Control Handbook for Developing Areas in West Virginia.

This handbook has been prepared in cooperation with the U.S. Department of Agriculture Soil Conservation Service, and the 14 locally governed Soil Conservation Districts. For further assistance in developing an erosion and sediment control plan, contact your local Soil Conservation District office or any office of the Soil Conservation Service.

Gus Douglass
Chairman, West Virginia
Soil Conservation Committee

Assistance from the Soil Conservation Districts

West Virginia has 14 soil conservation districts which serve all parts of the state. The districts are subdivisions of the state, and they are directed by boards of supervisors from within their borders. The supervisors give local direction and coordination to various government agencies providing help to the public. They provide needed services in getting conservation practices on the land. The agency which works most closely with the soil conservation districts is the Soil Conservation Service of the U.S. Department of Agriculture.

When districts were organized in the 1940's they spent almost all of their energies and resources assisting individual farmers. Conservationists helped farmers plan and use each acre within its capabilities and treat it according to its needs.

In more recent years, the districts also offered their services to other landowners and land users. These included those persons concerned with controlling sediment production, and managing storm water on developing areas—planners, leaders in local government, builders, industrial managers, educators, and others who needed to disturb land, but who wanted to conserve soil and keep sediment out of streams.

It was important that farmers, as well as developers and other land users, obtain the assistance of professional conservation technicians "before the bulldozer moves in." Soil and related water resources have definite limitations. If these limitations are disregarded in the construction of homes or development of business and industrial areas, resulting mistakes can cost many thousands of dollars later. Also, the district supervisors are especially concerned about the worry and heartache caused individual home owners by inadequately planned construction. For them as for farmers, the soil is the first and final foundation for what they are constructing.

That's why I am so pleased about the updating and republication of West Virginia's "Erosion and Sediment Control Handbook for Developing Areas." The developer, or the individual building a home, can take this book and make his own checklist of factors to be considered and actions to be taken to assure the best and, in the long run, least costly development.

Of course, besides this book, the districts are still present and offer assistance in all parts of West Virginia. Working with the SCS and other federal and state agencies, we can tailor assistance to meet your needs, whether you are running a corporation or trying to decide how to build your own home. Use this book, or use the assistance, or use them both together. We exist to serve you, and we want to do that well.

Boyd Meadows

Boyd Meadows
President West Virginia Soil
and Water Conservation District
Supervisor's Association

Assistance from the Soil Conservation Service

Technical assistance to help individuals, groups, and units of Government plan and establish needed soil and water conservation practices is provided by the Soil Conservation Service through fourteen local soil conservation districts in West Virginia.

The Service (SCS) is the United States Department of Agriculture's technical arm of action for conservation of soil and water resources. Its staff includes soil scientists, engineers, biologists, agronomists, foresters, plant materials specialists, geologists, and soil conservationists. All of these disciplines are brought together by the soil conservationists to help solve land and water conservation problems.

There are field offices located throughout West Virginia to provide technical help in all 55 counties in the State. SCS professional employees advise individuals, planners, builders, developers, and engineers on soil interpretations, proper land use, erosion and sediment control, storm water management, and numerous problems associated with soil and water conservation. Technical assistance may be on site or consultative in nature.

The policy of the Soil Conservation Service is not only to protect and preserve, but to restore and renew soil and water resources in the State and Nation.

Rollin N. Swank
State Conservationist
USDA Soil Conservation Service

Assistance from other Federal and State Agencies

The need has been growing for two decades for cooperation to solve conservation problems in developing areas. The cooperation, to work effectively, had to involve many agencies, organizations, groups, and individuals.

The Clean Water Act of 1987 requires that each state develop and submit a Non-Point Source (NPS) Assessment Report and Management Program to the Environmental Protection Agency (EPA) for approval. Programmatic and technical expertise is essential to the initiation and operation of a successful NPS program. Under agreement with the West Virginia Department of Natural Resources, the State Soil Conservation Committee has been designated as the management agency for implementing agriculture and construction components of NPS programs in West Virginia. The Committee has responsibility for carrying out State programs dealing with non-point source pollution management programs.

The voluntary state plan strongly encourages those engaged in construction activities in developing areas to prepare sediment control plans and have them reviewed by the State Soil Conservation Committee for technical adequacy. An educational program for both the public and the construction industry is a major part of the plan.

West Virginia's Department of Natural Resources must report annually to the U.S. Environmental Protection Agency (EPA) the progress being made in improving water quality. This handbook should provide information useful in implementing the water quality management plan.

Many agencies must cooperate in the effort. In the U.S. Department of Agriculture, the Soil Conservation Service offers technical assistance. Other USDA agencies helping with land-development conservation include the Agricultural Stabilization and Conservation Service; the Economics, Statistics, and Cooperative Service; the Cooperative Extension Service, operating as a part of West Virginia University; and the Forest Service. They offer a variety of services ranging from financial assistance to research and educational programs.

Other Federal, State, and local agencies also are involved. The EPA has overall national responsibility for reduction and prevention of pollution in the environment. The Office of Surface Mining of the U.S. Department of the Interior regulates reclamation of lands disturbed by coal mining activities. The West Virginia University Agricultural Experiment Station provides chemical analysis of soils to aid in land stabilization. The State Department of Environmental Protection, Division of Natural Resources, Water Resources Branch, has major responsibilities in maintaining water quality. The State Department of Environmental Protection, Enforcement and Abandoned Mine Lands Divisions have major responsibilities in mine reclamation. The State Department of Highways is responsible for controlling erosion and sediment during highway construction. The West Virginia Department of Health has responsibility for problems of health and sanitation. The State Geological and Economic Survey is concerned with geology, hydrology, and preservation of scenic and historical areas.

Local governments establish land development policies and are responsible for community planning. Local government is the developer when public land is used for schools, parks, and other public purposes.

Managers in industries and businesses also share in the responsibility for preventing water pollutants from leaving developing areas. Finally, developers and individuals building homes need to work closely with government agencies toward solving their own conservation problems.

Section 2
Resource Planning

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The Problems

Housing, industry, transportation, and recreation are taking increasing amounts of land in West Virginia. These uses invariably disturb the land and that produces a two-headed problem of soil erosion and sedimentation.

Erosion

Disturbed land erodes more easily than land in a natural condition. Soil erosion involves the detachment of soil particles by water or wind, causing them to move.

The rate of soil erosion is affected by rainfall intensity, soil type, steepness and length of slope, vegetative or other protective cover, and the length of time the soil is exposed to water and/or wind.

The four types of soil erosion in West Virginia are splash, sheet, rill, and gully.

Raindrops have an explosive effect on bare soil.

Pillars left under stones sometimes indicate the almost invisible loss of soil by sheet erosion.

The difference between rill and gully erosion is in the size of channels cut by eroding water.

Gully erosion consists of more deeply eroded channels.

Splash Erosion is the detachment of soil particles by the impact of raindrops. It loosens the soil and causes it to be subject to movement.

Sheet Erosion is the most deceptive type. The soil is lost in a uniform layer from a particular area similar to removing sheets of paper from a tablet. The loss is hard to detect unless the soil depth is measured frequently. This type of soil erosion usually occurs on areas with uniform slopes and which have received an even distribution of surface runoff or wind.

Rill and Gully Erosion are similar, differing according to the degree of erosion that has taken place. Where surface runoff is allowed to concentrate on a specific area, small valleys or cuts called rills are formed in the soil. If the erosion continues unchecked, these rills will enlarge and combine into larger cuts called gullies.

Soil erosion is most critical just after the land has been disturbed. The initial disturbance loosens the soil and makes it easier to be transported by water or wind.

Soil erosion creates ugly scars on our landscape. It damages public and private property. Fertile topsoil lost from an area where it has taken years to develop is irreplaceable. Repairs of erosion are costly. Roads and bridges wash out and pavements fail due to undercutting. Pipelines and other utilities are damaged. Eroded soil loses its ability to hold water. Faster runoff of water increases flooding.

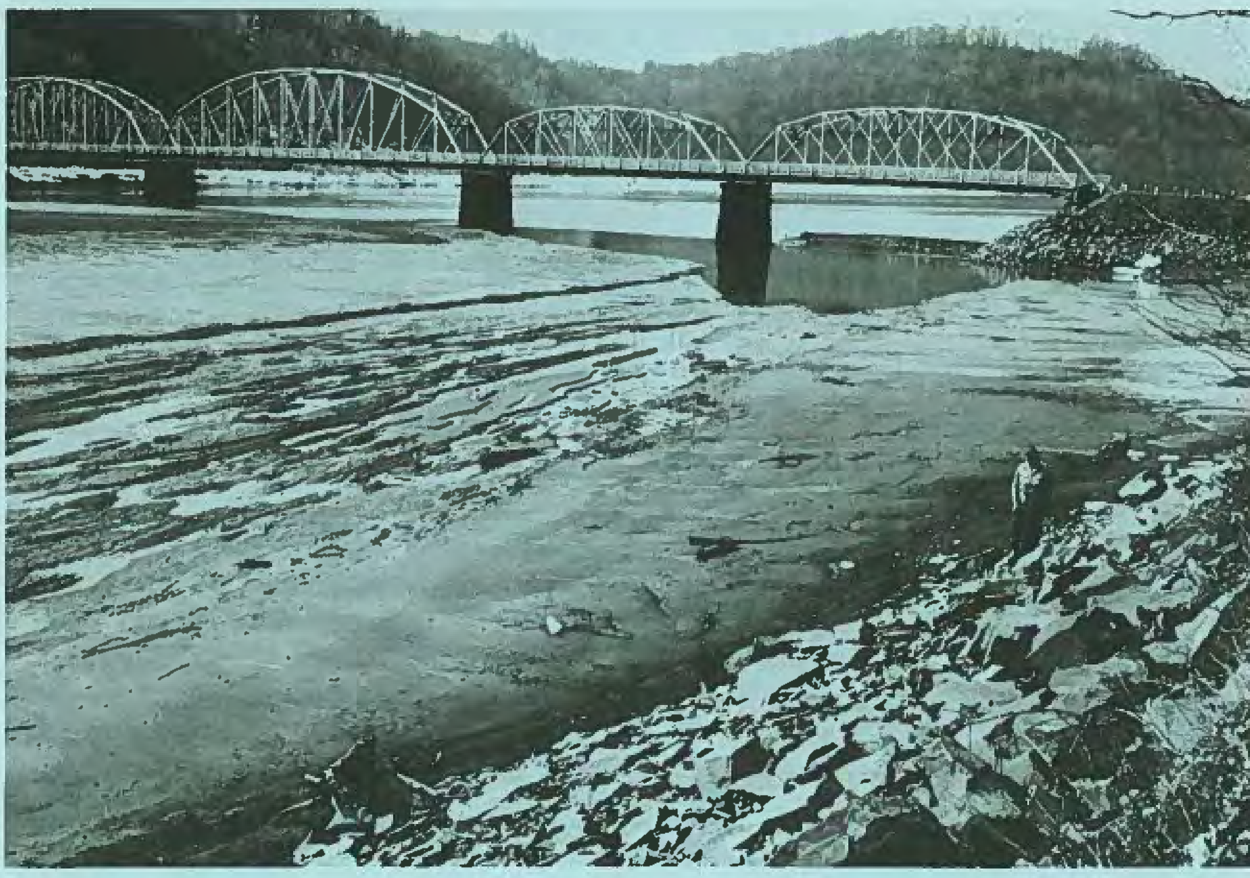
Sediment

The second part of the problem is damage to land and water below the eroded area. Misplaced soil, known as sediment, covers other areas and clogs streams and lakes. The removal of sediment is costly and never ending if the erosion above is not reduced and controlled.

Sediment damages lawns, roads, recreation areas, and buildings. It reduces the capacity of ditches, drains, and culverts. It pollutes streams and rivers, causing increased flooding, higher costs for purifying drinking water, and the death of fish and other aquatic life. It can carry pesticides and affect the aesthetic appearance of the environment.

Sediment fills ponds, lakes, and reservoirs and depletes valuable water storage capacity that could otherwise be used for recreation, water supply, and flood control.

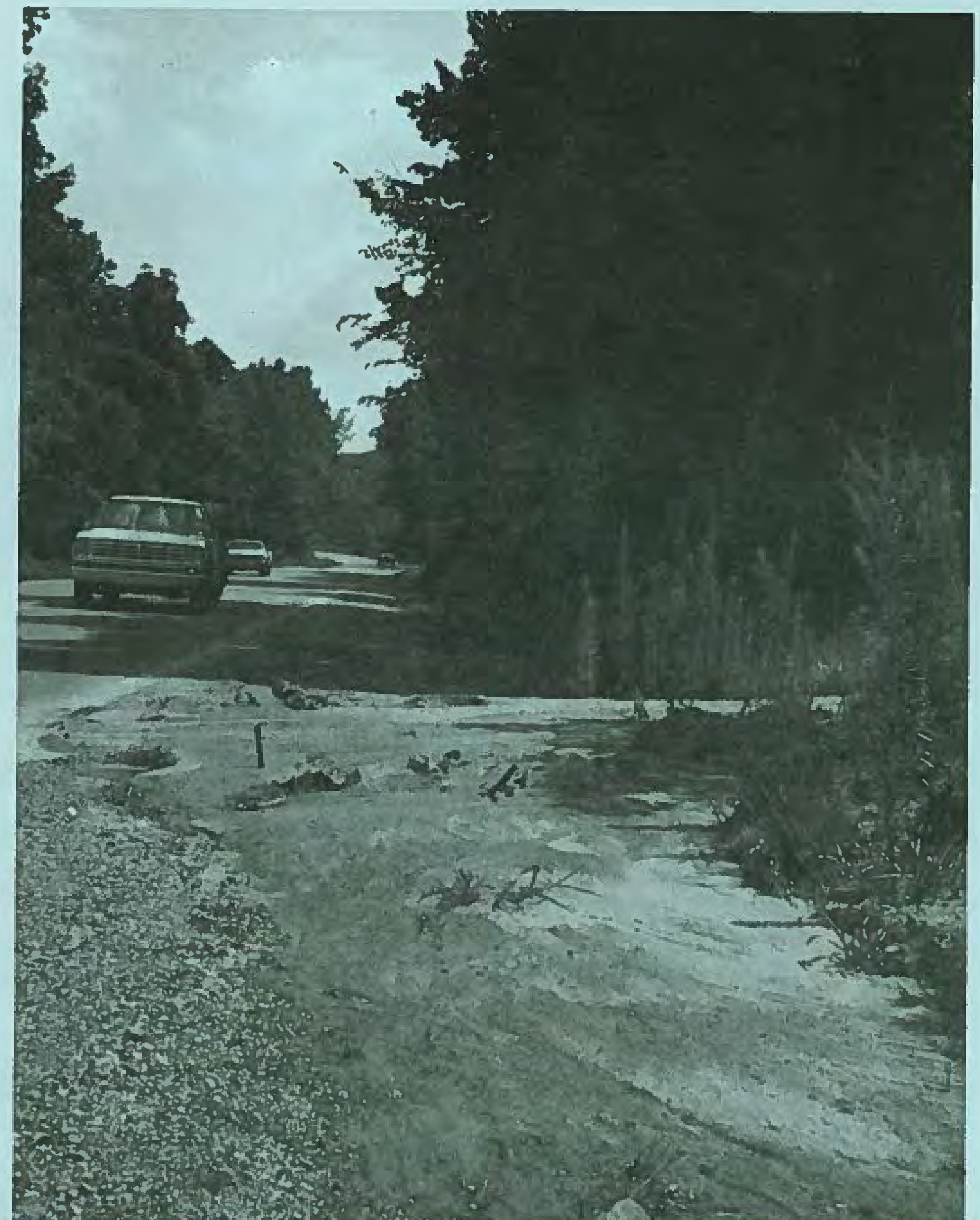
The capacity of this inlet has been reduced by sediment.



This lake (above) and pond (below) are in the process of being destroyed by sediment.

The left channel under this railroad bridge was totally closed by sediment in less than 10 years.

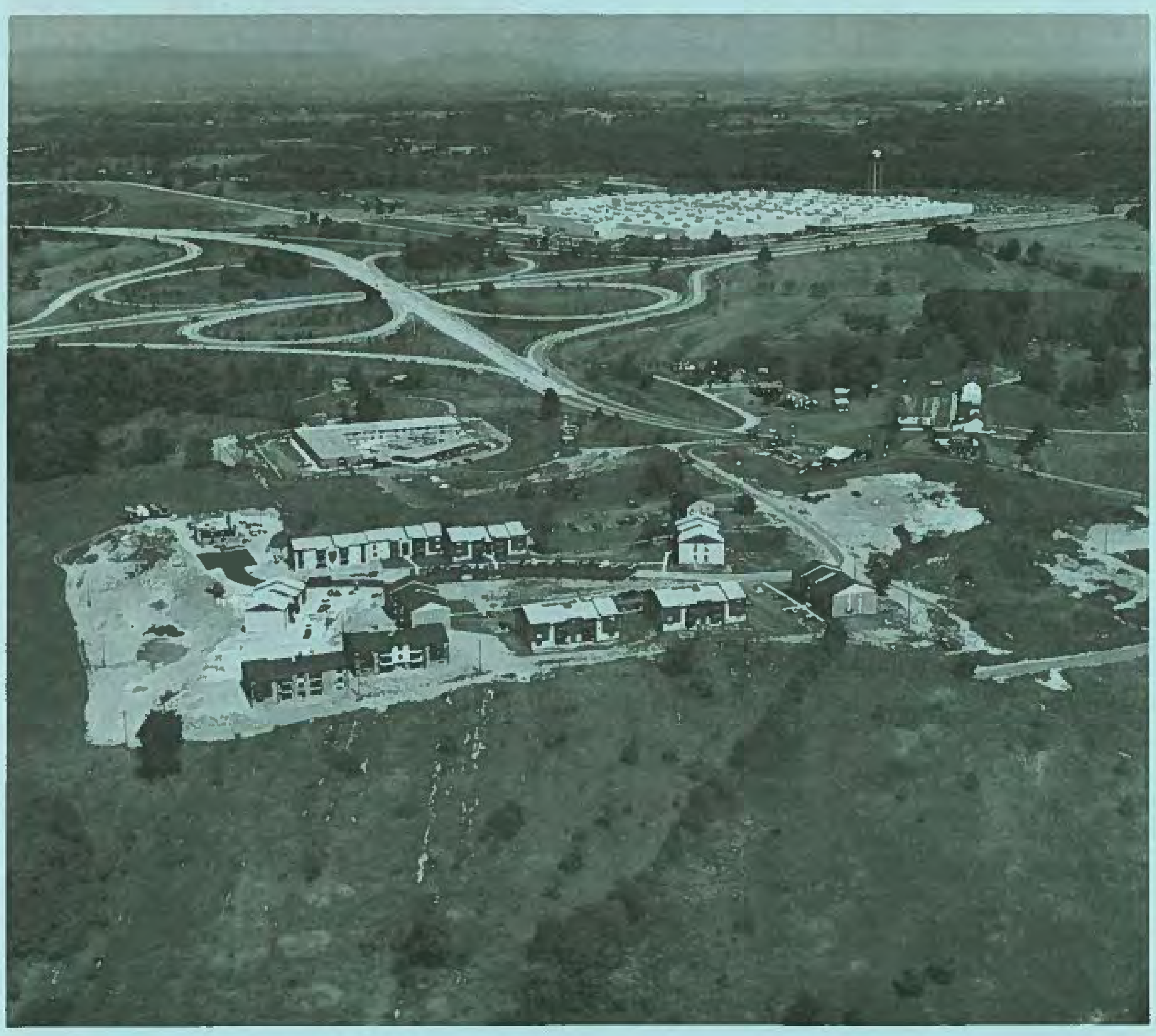
Accumulation of sediment restricts navigable waterways and fills locks, bays, and harbors. These areas have to be dredged periodically in order to maintain their use.



This is a road ditch being filled from a nearby construction site.

In terms of volume, sediment is the major water pollutant in West Virginia. Attached to sediment can be harmful bacteria, nematodes and other disease-causing agents.

The two-headed problem of erosion and sediment can be beaten with a two-headed answer — (Proper Planning and Installing Effective Measures).



Intensive development, leading to disturbance of soil, may include housing, motels, highways, and factories. Solutions to erosion and sedimentation are needed both during and after construction.

Proper Planning

Proper planning in land use development recognizes that land is a limited resource and has many physical variations which need to be considered prior to development. Proper planning provides conservation and wise use of the soil, water, and related resources. Use of soil survey information to get the facts about the land, including erosion and sediment control, is one of the first steps to proper planning.

Land is a Limited Resource

Major consideration must be given to prime farmlands and the long-range need to retain the productive capability and environmental values of American agriculture and forestry. Developments that result in irreversible land use changes represent a loss of valuable resources. West Virginia has approximately 500,000 acres of land that are considered prime farmland. The long-term implications of the land use conversions on the productive capacity of our farmland should be evaluated.

Soil conservation districts play a major role in planning proper land use through programs in erosion, sediment, and water quality control.

Most of the land in West Virginia is steep and very susceptible to soil erosion and sedimentation. Since mounting pressures upon land are constantly making this resource more and more valuable, it becomes increasingly evident that future developmental pressure is going to be on the steeper, more erodible soils. Therefore, careful assessment of the land as a natural resource base is a necessary first step toward planning the development of an area. Future urban and rural development must be carefully adjusted to that base if serious environmental problems are to be avoided.

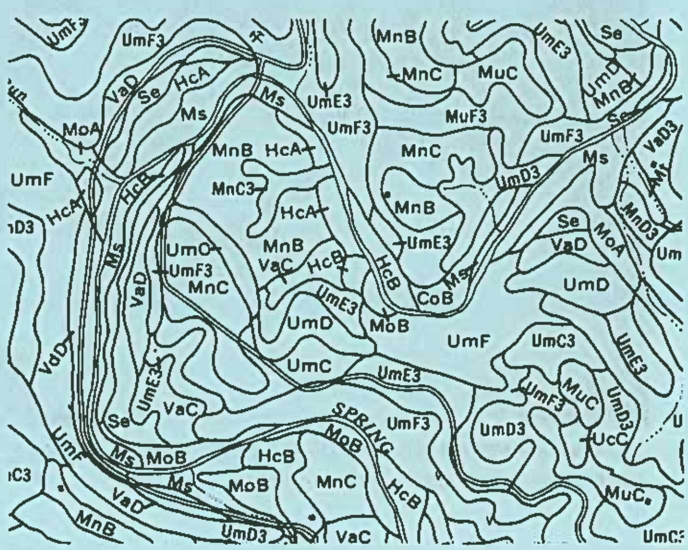
Know Your Soil

One of the first steps in minimizing problems involving land use and development is to know the soils and select the best possible site for the use intended. Soil properties exert a strong influence on the manner in which people use and should use the land. Soil properties should be recognized prior to development to prevent costly mistakes. With the limited level land in West Virginia, much of which is subject to flooding, development will increase on the more sloping upland areas. If the soil properties of this land are recognized prior to development, problems can be minimized.

Soil Surveys Can Help

Soil surveys are basic inventories of the soil resources of an area. They can be used as a tool in determining soil limitations for many rural and urban uses. These surveys include soil maps, soil descriptions, and soil interpretations. This information is available in published soil surveys for several counties in West Virginia. Many additional counties have mapping completed which is available in the local Soil Conservation Service field offices in the State. Technical assistance, relating to soil, is available for all 55 counties in West Virginia through the 14 soil conservation districts.

Farmers and agricultural planners have used soil surveys for many years as a guide to land use and treatment. Urban planners, engineers, sanitarians, foresters, builders, Realtors, and others now recog-



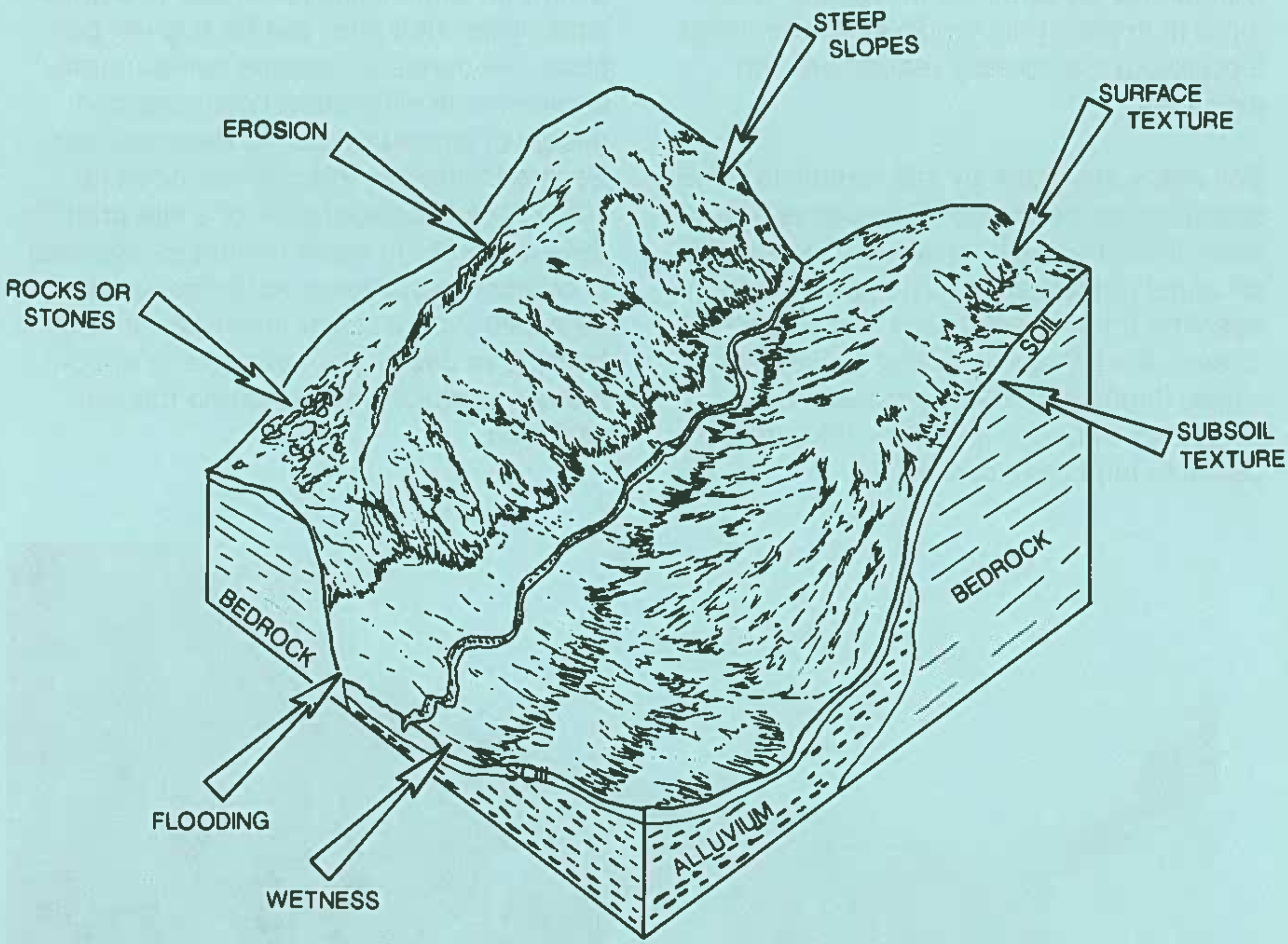
Soil surveys provide a map showing the location, extent, and kinds of soils. The map also shows other natural and man-made features.

nize the usefulness of soil surveys as an aid in selecting sites and designing structures to minimize soil related problems. Sometimes adjustments in locating structures to avoid highly erodible soils or steep topography can greatly reduce erosion problems.

Soil maps are made by soil scientists. The scientists locate the soil boundaries and other features, such as streams and roads, on aerial photographs. The soil surveys describe the characteristics and properties of each kind of soil including soil texture, slope, depth, erodibility, permeability, degree of wetness, and other information useful to land developers.

Soils are rated according to their limitations for a given use. These soil limitations are expressed as slight, moderate, or severe. Soils with slight limitations have few problems which limit their use for a given purpose. Moderate limitations can generally be overcome with careful planning and design of structures during development. Severe limitations indicate the need for very careful consideration of a site prior to development. In some instances, the cost of overcoming a given soil limitation may be excessive. In other instances, it may be feasible to design the structure or adopt measures which will overcome the soil limitation.

Urban planners and others use soil surveys as a tool in land development.



Get the facts from soil surveys.

Some of the common soil-related limitations in West Virginia are flooding, high shrink-swell, shallowness to bedrock, wetness, slipping, slow permeability, and very steep slopes. Examples of resulting problems are flooded buildings and other structures, cracking and failing building foundations, wet basements, collapsing roadbeds, malfunctioning septic tank systems, excessive erosion, and sedimentation damage. Measures necessary to help overcome these problems are much easier to identify once the soil-related problems are recognized. However, it is important that a competent consultant, engineer, or technician be contacted for on site investigation and subsequent design of structures for development.

Include Erosion and Sediment Control in the Plan

A high percentage of the land remaining for future development in West Virginia has sloping soils that are very susceptible to erosion when disturbed by construction. Therefore, it is extremely important that a program for erosion and sediment control is worked out during the planning and design stages, before ideas become fixed and construction begins.

Special consideration should be given to the site and the landscaping of future developments. Proper street, lot, and building layout can minimize erosion during construction and complement the natural environment. Steep slopes, cut and fill slopes, and areas of highly erodible soils can be protected by conservation measures. Saving the natural vegetation, such as trees or shrubs, by minimum disturbance during grading can limit soil erosion. These are the kinds of considerations that need to be weighed and resolved during planning and design to get erosion control into the site development plan.

Where the cost of controlling erosion may be high because of site limitations, alternative land uses or a layout that is compatible with the landscape should be considered.

For example, in laying out a residential area on sloping land, fitting the buildings and streets to the natural characteristics of the land will help decrease erosion hazards and minimize development and maintenance costs. In using this method, houses are built only on the more level areas and the steep, more erodible land is left undisturbed.

The problems presented by small areas where erodible soils or steep slopes impose severe limitations may be solved best by using these areas as open spaces. Perhaps they can be added to public parks or to areas managed by community associations. In some places, schools make good use of them as nature areas or outdoor laboratories for class study.

There are alternative ways of effectively controlling erosion and sediment production on most sites. The final sediment control plan generally is based on such factors as the time of year that construction will take place, the extent of grading, the amount of cover on the land, and the builder's preferences. On most sites a combination of fitting the development to the land, limiting grading, limiting the time of bare soil exposure, and applying the appropriate erosion control practices will prove the most practical way to control erosion.

The following are some planning steps in controlling erosion and sediment:

1. Study the development area and evaluate soil characteristics, general topography, natural drainage, geology, and accessibility to determine site potential and identify site limitations.

2. Select a development plan that is compatible with site conditions.

3. Identify existing natural features that can be used in the development, such as vegetation, wildlife habitat, water areas, top soil available, etc.

4. Check with planning commission about local regulations that affect development of the area.

5. Prepare a plan for control of erosion and reduction of sediment during construction.

6. Plan construction so that certain areas may not be disturbed until they are needed.

7. Hold grading to a minimum and leave as many desirable trees as possible.

8. Provide for protection of areas disturbed that may be bare and exposed for long periods.

9. Control runoff by either diverting it off the site or conveying it safely through disturbed area. The structural measures considered include diversions, waterways, and closed drains.

10. Construct basins to store sediment and reduce surface runoff water during construction.

11. Provide for safe off site disposal of surface runoff water, including the increase resulting from development.

12. As soon as possible, establish perennial vegetation on areas where grading is finished.

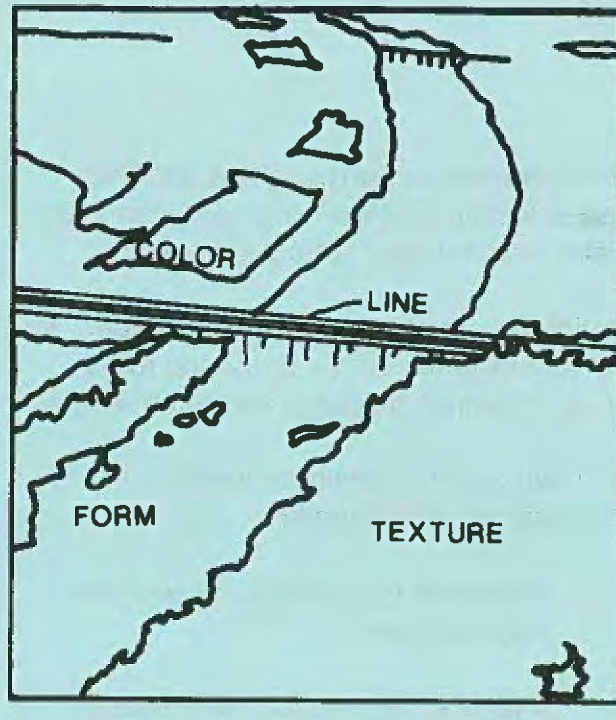
13. Provide for needed maintenance of conservation measures after construction is finished.

Landscape Resource

Landscape is a common sight to us all, although each of us has a different image. It is often influenced by the area where we live. People from the city probably picture a landscape as tall skyscrapers breaking the distant horizon line, whereas people from a rural situation may picture a landscape as a field with cattle grazing, a barn, and a pond. Although these two images are very different, their visual resource quality may be similar. The visual resource is the appearance of a landscape, and the visual resource quality is how appealing the landscape is to the observer.

Visual resource quality measures the aesthetic character of the landscape created by the combination of basic components such as line, form, texture, and color. The four basic components are represented by landforms, vegetation, water, and structures.

These basic components compete for visual dominance in the landscape and, in turn, influence the visual resource quality. Measuring visual resource is achieved by studying all the components and their effects on the total landscape. Visual resource planning is a very important part of the overall planning scheme. When introducing new elements or treating dis-



The elements for consideration in landscape architecture are form, lines, texture, and color.

turbed ones, the consequences of this work must be studied carefully. The objective of visual resource planning is to design, plan, and incorporate the components in a manner that will be aesthetically pleasing to the public.

Changes in a landscape create either positive or negative results, to various degrees, on the landscape.

Deterioration of the Reclaimed Landscape: Deterioration occurs when new elements are introduced and the effects are inadequately reclaimed. Little or no visual resource planning is the reason for this deterioration of the landscape.

Recession of the Landscape: Recession occurs when new elements are introduced and are inadequately incorporated into the landscape. Little or no visual resource planning is the reason for this recession of the landscape.

Destruction of the Landscape: Destruction occurs when the introduction of elements causes abrupt changes in the landscape. Damage is rapid and difficult to reverse.

Preservation of the Landscape: Preservation occurs when the elements of the existing landscape are incorporated into the proposed project. Minimal disturbance occurs, resulting from successful visual resource planning.

Enhancement of the Landscape: Enhancement of the landscape occurs when visual resource quality is improved with the introduction of the project. Enhancement is achieved with proper visual resource planning.

Modification of the Landscape: Modification occurs when the visual components created are unnaturally strong compared to the adjacent landscape. Treatment is needed to tone down the visual activity in an effort to create a landscape which complements its surroundings. Modification is a case of visual resource planning which has not been totally successful.

During the planning process, questions like the following should be proposed to address potential problems and alternatives:

- What is the dominant element in the existing landscape?
- Where are the points of view of the proposed site?
- What are the adjacent land uses?
- Are there water features present on the site?
- Are there any structures on the site?
- How does the proposed project relate to the surrounding landforms, vegetation, water, and structures?
- What views will be created by the proposed project?
- What is the dominant element of the proposed project?
- What consequences will the proposed project have on the existing landscape?

Visual resource planning is an important part of the overall planning process. If proper attention is paid to visual resource planning, a more aesthetically pleasing visual resource will result, enhancing the image of the developer and increasing the quality of the final project. Visual resources should be preserved for future generations to enjoy.

Fitting the buildings and streets to the natural characteristics of the land helps decrease erosion and minimizes development and maintenance costs.

Section 3
Vegetative Measures

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Vegetative Measures

There are two kinds of erosion and sediment control measures—structural and vegetative. For best results, these measures should complement each other. Establishing vegetation on recently disturbed or bare areas depends on several basic considerations. First, excess water which falls on the area and flowing from land above must be disposed of properly. This includes properly located and designed diversions, grassed waterways, subsurface drains, and stabilized outlets of different types.

Once the water has been disposed of, a second consideration is seeding and/or planting. This includes selection of plant species having characteristics enabling them to grow and hold the soil on a particular area. They fulfill a variety of other uses in addition to stabilization. Included in seeding and planting is consideration of the chemical nature (ability to supply plant nutrients) of the soil. Chemical tests will guide intelligent application of lime and fertilizer.

Third, when the water is controlled on a site and the area has been prepared and seeded, it must be protected from heavy use until plants can provide the needed soil protection for the planned uses. In some cases future use may always be so intensive that the only stabilization is a paved surface. For less intensive uses, protection may be provided in different ways such as fencing, or netting until vegetation is established. The primary objective of vegetative growth is stabilization of the area so that erosion is controlled and sediment losses are reduced to a minimum. Both permanent and temporary vegetative measures should be considered.

The types of protective vegetative cover should be included as part of the project plan. Planning for the erosion hazard, seeding needs, and implementation during construction will help eliminate serious problems later.

This highway bank was effectively stabilized with vegetation.

One very important guide is that seeding or planting of an area should be started as soon as possible after the area has been disturbed. A time limit in construction contracts for the length of time a site can remain unprotected is desirable.

Vegetative measures range from a simple seeding practice for temporary erosion control to a very complex sodding or seeding and planting (woody species) job. Temporary protection may include seeded species (annual or perennial grasses), or use of mulches (straw, wood chips, or barks), without seeding, or plastic, jute, erosion net or other synthetic material. Permanent protection may include such items as rock or gravel.

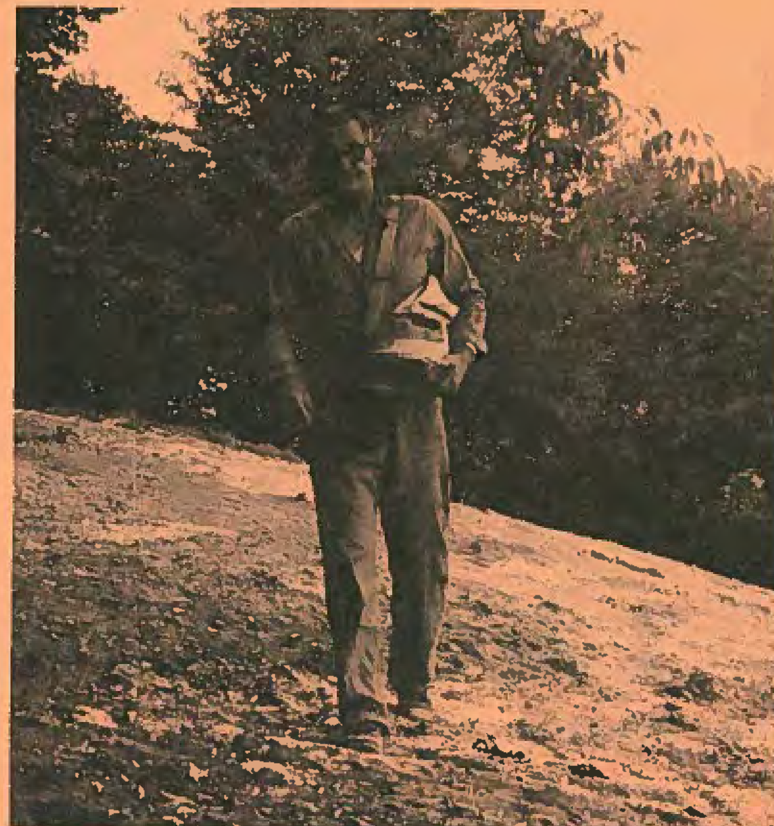
Grasses and legumes are used on graded and cleared areas where quick, dense cover is needed to reduce runoff and erosion. Mixtures may be used for temporary stabilization or for permanent protection where mowing and fertilization are feasible.

On areas having gentle slopes and adequate fertility, satisfactory protective cover can be established very easily. On steep areas where the subsoil has been exposed, the problems of establishment are more difficult. These areas require a combination of treatments. On soils where runoff water has been controlled, 1-1/2 to 1 slopes may be protected satisfactorily.

For best results, four elements are essential: proper planning, frequent follow-up during project installation, prompt establishment of vegetative measures, and proper maintenance.

Critical Area Planting

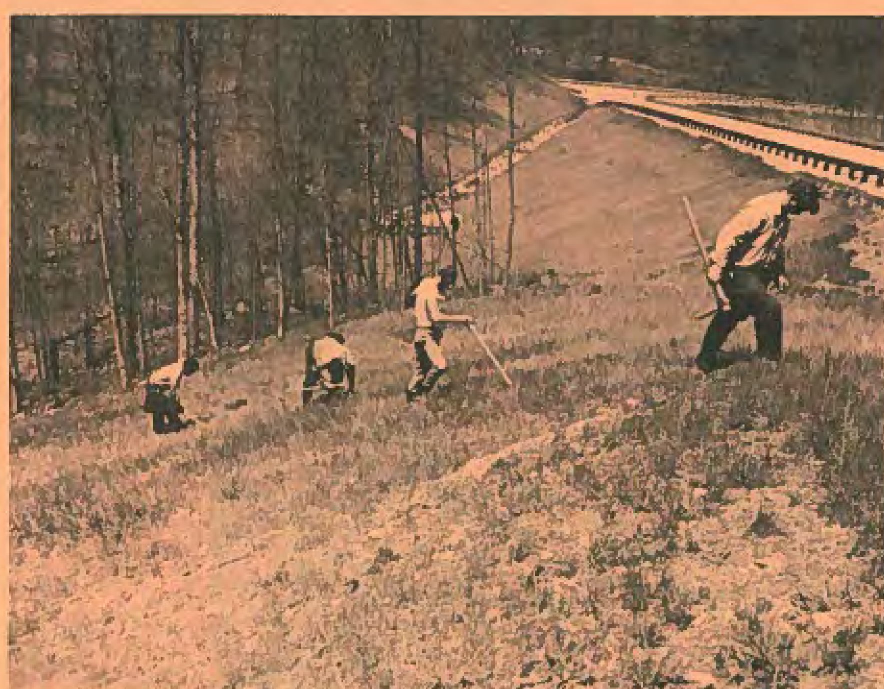
Critical area planting is the stabilization of critically eroding areas by the use of legumes, trees, shrubs, vines, and grasses secured by mulches. Plantings can either be temporary or permanent. Temporary plantings are usually used on areas requiring a quick cover for a short time. Partially completed construction projects are a good example. Land grading of a site may be partially complete when weather conditions prohibit further work during the winter months. A temporary planting of the unfinished grading should be accomplished as soon as possible. Permanent planting is the stabilization of an area for the life of the intended use and is undertaken after the grading has been completed. Examples include planting or seeding of roadbanks, school grounds, or areas around an industrial plant.



Above a cyclone seeder is being used to temporarily seed an area.

To the left is a permanent seeding of crown vetch on a steep highway bank.

Planting trees and shrubs on a steep highway bank helps to reduce erosion.



Tree planting is often combined with grass seeding to provide complete erosion control as well as beautification.

Temporary Critical Area Planting

Definition: Stabilization of sediment-producing areas on a short-term basis.

Purpose: To reduce runoff and erosion, thereby reducing damages from sediment downstream.

Where Applicable: Any area of exposed soil where no construction activity is anticipated for a period of longer than three weeks, but less tha. a year.

Specifications

Duration

1. Seed all topsoil piles, borrow areas, and cleared land which will not be paved, built upon or established in permanent vegetation for longer than three weeks, but less than a year, and all steep cut and fill slopes where no further activity will occur until final grading.

Fertilization

2. Apply 400 pounds per acre of 10-10-10 fertilizer.

Seeding Method

3. Broadcast or drill seed immediately after disturbance.

Mulching Seeding

4. Mulch the seeding immediately after seeding with two (2) tons of straw or weed-free hay per acre, wood fiber or mulch netting. Anchor straw or hay with asphalt emulsion, chemical anchoring solution, netting, or a mulch anchoring tool.

Mulching Alone

5. Mulch may be used alone to protect areas for less than three weeks or winter protection of areas exposed between November 1 and March 1. The mulch rate should be three (3) tons of straw or hay per acre when no seed is applied.

6. Species to seed, time of seeding, and rates:

Species to Seed	Seeding Dates	Pounds Per Acre	Pounds Per 1000 SQ FT
Oats	March 1 to June 15	96	2.40
Redtop	March 1 to June 15	5	0.12
	August 15 to September 15	5	0.12
Annual Ryegrass	March 1 to June 15	40	1.00
	August 15 to September 15	40	1.00
Millet	June 15 to August 15	30	0.75
Rye	August 15 to November 1	168	4.20
Wheat	August 15 to November 1	180	4.50

Permanent Critical Area Planting

Definition: Stabilization of sediment producing areas on a long term basis with herbaceous or woody plants.

Purpose: To stabilize eroding areas, reduce sedimentation, improve appearance, and produce wildlife food and cover.

Where Applicable: All kinds of disturbed land resulting from urban development (industrial, commercial, residential) as well as highway construction. Does not apply to lawn seeding, see lawn seeding standard.

Specifications

Herbaceous Plants

1. *Runoff Control* — Control runoff flowing across the site with temporary and permanent structures as necessary. Refer to structural measures section.

2. *Tillage* — Prepare the seedbed by tillage to a depth of 4-6 inches. Apply lime and fertilizer before the final tillage operation. Cultipack the seedbed.

3. *Liming* — Apply lime according to a soil test to correct the pH to 5.5 to 6.0. If a soil test cannot be analyzed before lime must be applied, apply three tons of ground limestone per acre (150 pounds per 1,000 square feet) and apply the balance recommended by the soil test when the test results are available.

4. *Fertilizer* — Apply fertilizer according to a soil test. If a soil test cannot be analyzed before fertilizer must be applied, apply 500 pounds of 10-20-10 (12 pounds per 1,000 square feet) and apply the balance recommended by the soil test when the test results are available. Apply maintenance fertilizer according to a soil test. If nitrogen applications cannot be split, nitrogen should be applied as urea-formaldehyde, or sulfur-coated urea.

5. *Seeding Method* — Sow seed by hydroseeder, drill, or broadcast and cultipacked. All spreaders should be calibrated before use. For even distribution, the seed should be divided in half and spread in perpendicular directions.

6. *Mulching* — Mulch the seeding immediately after seeding with two tons of straw or weed-free hay per acre, wood fiber, or mulch netting. Anchor the straw or hay with asphalt emulsion, chemical anchoring solution, netting, or a mulch anchoring tool.

7. Species to seed and rate of seeding:

		Drainage Adaptation[5]	
Species[2]	Seeding Rate (# per acre1	Excessively Drained	Poorly Drained
Tall Fescue	60	x	x
Tall Fescue and	40	x	
Red Fescue or	10		
Hard Fescue	10		

Drainage Adaptation[5]

Species[2]	Seeding Rate (# per acre1	Excessively Drained	Poorly Drained
Tall Fescue	20	x	x
Bird's-foot Trefoil[3]	6		
Red Fescue or	20	x	
Hard Fescue	20		
Bird's-foot Trefoil[3]	6		
Tall Fescue or	20	x	
Red Fescue or	20		
Hard Fescue	20		
Sericea Lespedeza[3]	10		
Reed Canarygrass	20	x	x
Reed Canarygrass	15	x	x
Bird's-foot Trefoil[3]	6		
Crown vetch[3] and	20	x	
Tall Fescue or	20		
Red Fescue or	20		
Hard Fescue or	20		
Perennial Ryegrass	20		
Flatpea[3] and	40	x	
Tall Fescue or	20		
Red Fescue or	20		
Hard Fescue or	20		
Perennial Ryegrass	20		
Perennial Pea[3]	40	x	
and Tall Fescue or	20		
Red Fescue or	20		
Hard Fescue or	20		
Perennial Ryegrass	20		
Switchgrass[4]	10	x	x

Drainage Adaptation[5]

Species[2]	Seeding Rate (# per acre1	Excessively Drained	Poorly Drained
Switchgrass[4]	10	x	x
Bird's-foot Trefoil[3] or	6	x	x
Sericea Lespedeza[3]	10	x	
Deertongue[4]	15	x	
Deertongue[4]	15	x	
Bird's-foot Trefoil[3]	6		
or Sericea Lespedeza[3]	10		

[1] Use the species listed in temporary critical area planting specifications as nurse crops at half the rate.

[2] Consult the Extension Service for forage and turf cultivar recommendations. Other species recommendations: Crown vetch — 'Penngift'; Flatpea 'Lathco'; Perennial Pea 'Lancer'; Sericea lespedeza 'Appalow'; Deertongue 'Tioga'; Switchgrass 'Blackwell' (erosion control) Shelter (wildlife habitat) 'Cave-in-Rock' (forage).

[3] Inoculate legume seeds, use four times the normal rate when hydroseeding.

[4] Use these mixtures on gentle, less erosive slopes.

[5] "x" indicates acceptable species for condition listed.

8. Date of seeding:

Cool Season Grasses and Legumes

Optimum — March 1 to April 15

Extended — November 15 to June 15
August 15 to September 15

Warm Season Grasses (switchgrass and

A cultipacker seeder is being used to seed a lawn during August, a desirable seeding month.

A hydroseeder will seed large areas. Fertilizer and seed are mixed with water in the hydroseeder tank and broadcast under pressure.

deertongue)
Optimum — March 1 to April 15
Extended — December 1 to April 15

Woody Plants

Woody plants can be used for erosion control on areas where long term stands are desired, mowing and frequent fertilization cannot be done, barriers, windbreaks, and hedges are needed, and also for shade and general improvement of the appearance of the area. Retaining existing desirable trees is an important consideration during site development. Vines are suitable for short, steep, or odd areas where mowing is not feasible and where permanent low-growing vegetation is desired.

Trees and shrubs planted around a home (above) can shelter it from winter winds. Trees saved during construction (below) will beautify and shade a home.

Uses and Characteristics of Plant Materials in West Virginia

All of us depend on plants for our survival, but through a lack of understanding or disrespect, we don't realize the benefits they can provide. Our attitudes are formulated by our perception of the environment surrounding us. Many times plants are stereotyped as being just cosmetic elements beautifying the landscape.

Plant materials provide many functions that we take for granted, such as space articulation, directing, regulating, and manipulating us through a space. Plants function as atmospheric purifiers capable of absorbing large quantities of noxious gases, objectionable odors, dust and dirt particles. These are just a few of the benefits that plants provide us every day of our lives.

The following tables will suggest some uses of plants commonly found in this part of the United States:

Many varieties selected for erosion control also beautify construction sites

TABLE 1 — Ground Cover, Vines, Shrubs, and Trees for Urban Areas in West Virginia

Common Name Botanical Name	Size Height-Spread	Growth Rate	Soil Suitability	Shade Tolerant	Diseases/Insects	Habit	Landscape Value	Winter Aspects	Spacing of Plants (Feet)
Washington Hawthorn (Crataegus phaenopyrum)	25' by 20'	Medium	Average Soil	1/2 or Full Sun	Fire-Blight	Upright, Columnar, Dense Thorny Tree, Rounded Crown, Multi-Stemmed, Some Irregular Growth	Attractive Specimen Plant, Screen, Border, Hedge, Nice Year Round, Good Fall Color, and Fruit-Red Lasts All Winter	Deciduous	5-9
European Black Alder (Alnus glutinosa)	40'-60' by 20'-30'	Fast	Tolerant	1/2 or Full Sun	Cankers, Leaf Rust, Mildew, Aphid, Lace Bug	Irregular Shape, Pyramidal Habit, Multi-stemmed	For Difficult Sites, Good In Sterile Soils, Can Fix Atmospheric Nitrogen	Deciduous	5-9
Japanese Larch (Larix leptolepis)	70' by 25'	Medium to Fast	Tolerates Wet Swampy Conditions	Full Sun or Light Shade	Larch Case-Bearer, Rust, Cankers, Wood Decay, Beetles	Narrow Pyramidal to Wide Spreading, Open Horizontal Branching	Fine Specimen, Good in Large Areas, Good Screen, Nice Character	Deciduous	5-9
Scotch Pine (Pinus sylvestris)	30'-60' by 30'-40'	Medium	Tolerant	Full Sun	Dry Rot, Fungus	Irregular Pyramidal, Open, Wide Spreading, Round-Topped	Picturesque Character, Specimen, Mass, Not a Shade Tree, Unique Form and Color, Rugged Conifer	Evergreen	5-9
Virginia Pine (Pinus virginiana)	15'-40' by 10'-30'	Slow	Very Tolerant	Full Sun	None	Broad, Open, Pyramidal, Irregular, Scrubby Appearance	Not Ornamental, Use In Poor Soils, Good Cover, Rugged Use Where Other Plants Will Not Grow	Evergreen	5-9
Common Juniper (Juniperus communis)	5'-25' by 8'-12'	Slow	Very Tolerant	Full Sun	Juniper Blight, Bagworm	Pyramidal, Ascending & Spreading Branches, Medium-Size	Handsome, Best for Poor, Dry, Sterile Soils, Very Tolerant	Evergreen	4-6
Eastern Red Cedar (Juniperus Virginiana)	30'-90' by 8'-20'	Slow to Medium	Very Tolerant	Full to 1/2 Sun	Cedar Apple Rust, Bagworms	Densely Pyramidal, Ascending Branches, Horizontal Branches In Old Age	Excellent Specimen, Mass, Windbreak, Shelterbelts, Hedge, Commercial Value	Evergreen	5-7

TABLE 2 — Ground Cover, Vines, Shrubs, and Trees for Urban Areas in West Virginia

Common Name Botanical Name	Size Height-Spread	Growth Rate	Soil Suitability	Shade Tolerant	Diseases/Insects	Habit	Landscape Value	Winter Aspects	Spacing of Plants (Feet)
Black Locust (Robinia pseudoacacia)	30'-50' by 20'-35'	Fast	Tolerant	Tolerant	Locust Borer, Canker, Leaf Miner	Upright, Open, Straight Trunks, Narrow Crowns, Ragged & Irregular with Age, Legume	Very Tolerant, Will Grow Just About Any-Where, Strip Mines, Cut & Fills, Flowers are Fragrant, Not for the Residential Landscape	Deciduous	8-10
White Pine (Pinus strobus)	50'-80' by 20'-40'	Fast	Tolerant	3/4 Sun	Blister Rust, Pine Weevil	Rounded to Pyram-idal, Horizontal or Ascending Branches-Distinctive Form	Very Handsome Speci-men, Mass, Sheared Hedge, a Beautiful Native Pine, Grows Well in Tough Areas	Evergreen	5-9
Northern White Cedar (Thuja occidentalis)	40'-60' by 10'-20'	Slow	Moist Soils, Deep Well Drained Soils	Full Sun	Bagworms, Spider Mites	Dense Broad Pyram-idal, Ascending Branches	Good Specimen, Accent Plant, Screen, Hedge, Windbreak, Good for Wet Sites	Evergreen	5-9
Eastern Hemlock (Tsuga canadensis)	40'-70' by 25'-35'	Medium	Well Drained Soils	Tolerant	Cankers, Rust, Blight, Leaf Miner, Scale	Pyramidal with Pendulous Branches, Dense Foliage	Graceful Hedge, Screening, Accent, One of Our Best Evergreens	Evergreen	5-9
Norway Spruce (Picea abies)	40'-60' by 25'-30'	Medium to Fast	Tolerant	1/2 Shade	Trunk & Root Rot, Budworm	Pyramidal, Pendulous Branches, Graceful, Stiff, Vigorous	Much Overused, Screen-ing Hedge, Windbreak, Critical Areas	Evergreen	5-9
Austrian Pine (Pinus Nigra)	50'-60' by 20'-40'	Fast	Very Tolerant	1/2 Shade	Dieback, Blight	Dense, Pyramidal, Broad Spreading Branches	Very Adaptable, Stiff Specimen, Screen, Wind-break, Mass	Evergreen	5-9

TABLE 3 — Ground Cover, Vines, Shrubs, and Trees for Urban Areas in West Virginia

Common Name Botanical Name	Size Height-Spread	Growth Rate	Soil Suitability	Shade Tolerant	Diseases/Insects	Habit	Landscape Value	Time To Form Cover (Years)	Spacing of Plants (Feet)
Arnold Dwarf Forsythia (Forsythia arnoldi)	4'-6'	Fast	Adaptable	1/2 Shade	Crowngall, Spider Mites	Low Dwarf, Arching Branches, Fibrous Roots, Stems Root When Touch Soil	Bank Cover, Ground Cover Massing, Critical Area, Yellow Flower	2	2-3
Fragrant Sumac (Rhus aromatica)	3'-8'	Slow	Adaptable	1/2 to 3/4 Shade	None Serious	Low, Irregular, Spreading, Suckers from Roots, Dense Stems, Root When Touch Soil	Fast Bank Cover, Mass-ing, Ground Cover, Critical Area, Yellow Flower	2	2-3
Hardhack Spirea (Spirea tomantosa)	3'-4'	Fast	Adaptable, Well Drained	1/2 Shade	None Serious	Upright, Clump, Branches Will Root	Mass or Naturalizing, Rose-Red Flowers	2	2-3
Black Chokeberry (Aronia melanocarpa)	3'-5'	Slow	Adaptable Wet or Dry Soils	Full or 1/2 Shade	None Serious	Suckers Profusely, Fibrous Roots, Upright, Spreading, Multi-Stemmed Shrub, Open, Leggy with Age	Good in Wet Areas, Naturalizing, Border, Massings, Attractive Fruit, Red Fall Color	2-3	2-3
Siebold Forsythia (Forsythia suspensa seboldi)	3'-9' by 7'-10'	Fast	Adaptable	Full Sun	None Are Extremely Serious	Pendulous, Arching, Spreading Shrub, Branches Root Rapidly, Vigorous Growth	Flower Color Yellow, Can be Used Effectively, Good for Bank Protec-tion, Mass, Border	2	3-4
Snowberry (Symphoricarpos albus)	3'-6' by 3'-6'	Fast	Very Tolerant	Full to 1/2 Shade	Authracinose, Berry Rot Rust	Bushy, Ascending Shoots, Twiggy	Fruit Can be Interest-ing, Good for Stabiliz-ing, Cuts, Slopes, Fills, Ornamental Fruit	2	2-3
Billard Spirea (Spirea billardi)	6'-6'	Fast	Tolerant	f/2 to Full Shade	None Serious	Erect Arching, Shrub Increases by Under-ground Stems, Quickly Forming a Dense Mass of Growth	Mass Planting, Slopes, Nice Flowers, Rose-Red	2	2-3

TABLE 4 — Ground Cover, Vines, Shrubs, and Trees for Urban Areas in West Virginia

Common Name Botanical Name	Size Height-Spread	Growth Rate	Soil Suitability	Shade Tolerant	Diseases/Insects	Habit	Landscape Value	Time To Form Cover (Years)	Spacing of Plants (Feet)
Red-Osier Dogwood (Cornus stolonifera)	9'-10'	Fast	Very Adaptable	1/2 to Full Shade	Canker, Scale	Loose, Broad-Spreading, Rounded Multi-Stemmed Shrub, Horizontal Branches Found in Swampy Areas, Branches are Bright Red	Excellent for Massing, Shrub Border Bank Cover	2	3
Bayberry (Myrica pensylvanica)	5'-12' by 9'	Medium	Adaptable, Good in Poor Soils	1/2 to Full Shade	None Serious	Deciduous-semi-Evergreen, Upright, Rounded, Dense, Withstands Salt-Spray	Excellent in Mass, Border, Use in Poor Soil Sites, Aromatic Leaves, Showy Berries	3	3
Winter Creeper (Euonymus fortunei)	4"-6" Spread 10'	Fast	Tolerant	Tolerant	Crown Gall, Aphids, Scales	Evergreen, Ground Cover or Vine	Excellent on Steep Slopes, Ground Cover, Vine, Wall Cover, Low Hedge, Forms a Weed Free Mat	1-2	1-2
Virginia Creeper (Parthenocissus quinquefolia)	Spread 15'	Fast	Tolerant	Tolerant	Canker, Mildew, Leaf Spot, Beetles, Scales	Deciduous Vine, Ability to Cement Itself to Walls, Very Long Branches, Difficult to Kill	Tough, Low Maintenance Cover, Will Cover Any-thing, Walls, Trellises, Rock Piles, Slow to Reestablish	2-3	2-3
Korean Bittersweet (Celastrus flagellaris)	Spread 20'	Fast	Tolerant	Full Sun	Leaf Spots, Aphids, Mildews, Crown Gall, Canker	Vigorous, Deciduous Vine, Quick To Cover, Twining Vine	Tough Plant, Best Used Only in Hard to Establish Areas, Allow to Ramble, Thorny Branches, Handsome Fruit, Good Barrier Plant, Will Grow as Long as There is Something to Grow on	1-2	2-3

TABLE 5 — Ground Cover, Vines, Shrubs, and Trees for Urban Areas in West Virginia

Common Name Botanical Name	Size Height-Spread	Growth Rate	Soil Suitability	Shade Tolerant	Diseases/Insects	Habit	Landscape Value	Time To Form Cover (Years)	Spacing of Plants (Feet)
Creeping Juniper (Juniperus horizontalis)	2'-4'	Slow to Medium	Very Tolerant	1/2 Shade	Juniper Blight Can be Extremely Serious	Low Prostrate, Long Tailing Branches Forming Dense Mats	Valued for Adaptability to Soils Tolerates, Hot, Dry, Sunny Locations, Used on Slopes as Ground Cover, Massing	2-3	3-4
Sargent Juniper (Juniperus chinensis sargenti)	18"-24" by 7'-9'	Slow to Medium	Alkaline Moist, Well Drained Soils	1/2 Shade	None Serious	Low Prostrate, Creeping, Forming a Dense Mat, Tolerates Salt-Spray	Excellent Ground Cover or Mass Plant	2-3	3-4
Canadian Yew (Taxus canadensis)	3'-6' by 6'	Slow	Moist Sandy Loam	1/2 Shade	None Serious	Loose, Straggling, Long-Lived Shrub, Leader Branches Root in Ground	Ground Cover In a Cool Shaded Situation	2-3	2-3
Pfitzer Juniper (Juniperus chinensis pfitzeriana)	5'-10'	Slow to Medium	Alkaline Moist, Well Drained Soils	1/2 Shade	Juniper Blight	Wide, Spreading Varies in Form, Long-Lived	Slope Cover, Critical Area, Massing	2	3-4
Japanese Yew (Taxus cuspidata)	Variable 10'-40' by 30'	Slow	Well Drained But Adaptable	Tolerant	None Serious	Irregular, Spreading or Upright-Spreading, Multi-Stemmed Shrub or Tree Long-Lived	Excellent for Screen, Hedge, Mass, Bank Cover	2-3	3
Mugo Pine (Pinus mugo)	8'-15' by 20'	Slow	Deep Moist Loam	Tolerant	Scale Rust, Wood Rot, Borers, Sawflies	Variable, Prostrate or Pyramidal, Low Broad Spreading, Bushy Plant	Masses, Hedge, Critical Area Plantings, Dwarf Forms are Used Extensively, Tremendous Variety in Size	3	3

Table 6 — Ground Cover, Vines, Shrubs, and Trees for Urban Areas in West Virginia

Common Name Botanical Name	Size Height-Spread	Growth Rate	Soil Suitability	Shade Tolerant	Diseases/Insects	Habit	Landscape Value	Time To Form Cover (Years)	Spacing of Plants (Feet)
Bugle Weed (Ajuga reptans)	4"-12"	Fast	Well Drained Acid Soils	Prefers Shade	None Serious	Perennial Evergreen, Spreads by Runners	Excellent Ground Cover Under Other Plants, Accent or Border Plant, Specimen or Mass Plantings	2	1
Lilyturf (Liriope muscari)	8"-12"	Medium	Tolerant	Tolerant	None Serious	Dense Spreading, Semi-Evergreen Spreads by Underground Stems	Ground Cover for Shady Slopes, Salt Tolerant	2	1
Tawny Daylily	18"-24"	Medium to Slow	Tolerant	Tolerant	None Serious	Slow to Cover, Sparse at First	Needs Companion Cover Crop, Mass Plantings, Critical Area	2-3	1-2
Baltic English Ivy (Hedra helix baltica)	6"-12"	Fast	Somewhat Tolerant	Tolerant	Leaf Spot, Canker, Aphids, Caterpillars	Low Hugging, Evergreen, Ground Cover	Ground Cover Can be Used in Heavy Shade, Vigorous	2	1
Common Periwinkle (Vinca minor)	3"-6"	Medium to Fast	Tolerant	1/2 Shade	Blight, Canker, Leaf Spots	Low Growing, Prostrate Evergreen, Forms a Dense Mat	Excellent Ground Cover, Dainty Blue Flowers	1-2	1
Littleleaf Cotoneaster (Cotoneaster dammeri radicans)	10"-15"	Fast	Tolerant	Tolerant	Aphids	Low, Prostrate, Evergreen, Semi-Evergreen, Creeping Branches	One of the Best Evergreen Ground Covers, Banks, Masses, or Shrub Border	2	1
Japanese Spurge (Pachysandra terminalis)	6"-12"	Slow	Moist, Well Drained Acid Soil (pH 5 . 5-6 . 5), Organic Matter	Shade	Blight, Scale, Mites	Evergreen, Ground Cover, Spreading by Rhizomes	Best Ground Cover for Deep Shade, Critical Areas	2	.5-1

Protecting Trees During Construction

Saving trees during and after construction activities has many advantages. These include erosion control, aesthetic and monetary values, wildlife enhancement, screening, and protection from wind. These factors are important in considering the number, kind, and location of trees to be retained and protected.

Other evaluations need to be made in deciding which trees to save. These are species, size, age, vigor, cost, work involved in preserving trees, and adaptation of trees to environmental changes. Tree species vary in their characteristics, and this must be considered carefully in selecting trees to be saved. Maples, willow, dogwood, and most conifers are shallow-rooted and may hinder the desirable growth of lawns and certain ornamental shrubs. Willows and some poplars may clog tile or sewer lines. Some trees are more susceptible than others to insects and diseases. Poplar, willow, and locust adapt more easily to environmental changes. Less adaptable trees are beech, birch, hickory, tulip tree, some oaks, most apples, and most conifers. Old or large trees do not adapt to environmental changes as well as young trees of the same species.

On this urban development some trees have been saved.

Trees need to be protected from damage by construction equipment, storage of supplies, changed ground surface elevation (either higher or lower), and excavation near the root zone. To protect a tree against mechanical injury, construct a simple fence or other barrier around it. Enclose an area at least 10 feet square with the tree in the center for small trees and larger for mature trees. All roots subject to soil compaction or mechanical injury should be inside the barrier to prevent damage from vehicles and construction equipment.

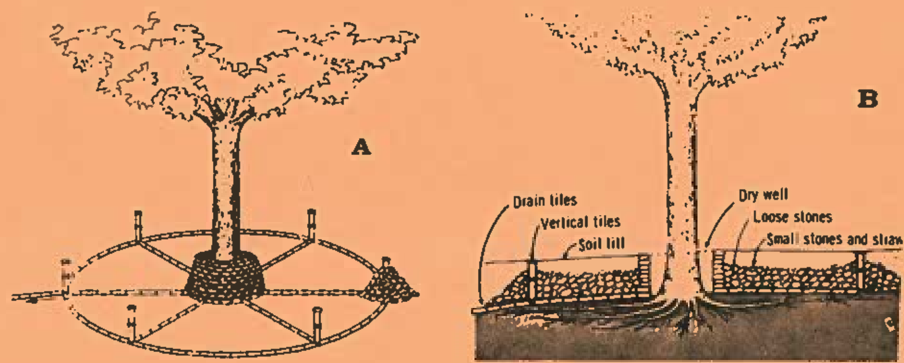
Tree roots need air, water, and minerals to survive. Any changes in the elevation of the ground surface will affect these important ingredients and a tree may have difficulty in obtaining normal amounts of each. In raising the ground surface elevation, minor fills—6 inches or less in depth—may not do any harm if soil is fertile and has good tilth. Major elevation increases usually require gravel layers and tile drain systems (Figure 1). Tiles are laid on original grade in the form of spokes of a wheel. The "spokes" open into a dry well built around the trunk. It may be necessary to place a series of bell tiles vertically over the roots and connect them to the rim of the wagon wheel system to allow for additional air and water circulation. The air system will have to be designed for each tree individually, and it will have to fit the contour of the land so water drains away from the tree trunk. Water concentrated from dwellings, parking areas, or faulty septic tank drainage fields may also cause damage or death to trees.

Protecting a tree from a lowered ground surface is usually less complicated than protecting it from a raised grade. Generally, protection is achieved by terracing. If space is available, the tree may be unharmed by letting it remain on a gently sloping mound. Another way to protect it from a lowered ground surface is to build a retaining wall between it and the lower grade (Figure 2).

Trees can be protected from underground utility lines. If the route cannot be diverted around the tree, tunneling under it may be necessary (Figure 3). In tunneling, cut as few roots as possible, cut them clearly, paint cut root ends with a wound dressing, such as asphalt-based paint, and backfill the trench as soon as possible to keep roots from being exposed to air. Figure 4 also illustrates various types of tree wells. Cost of tunneling must be considered against the value of trees to be saved.

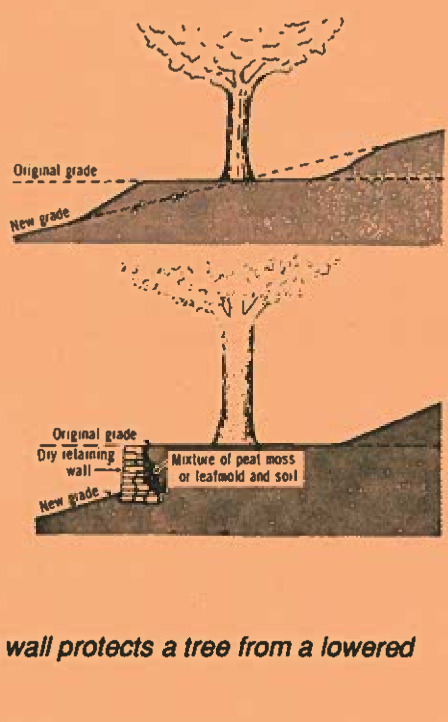
There may be occasions when the only way to save a tree is to move it. It is best to move trees when they are dormant. Practically no kind of plant can survive if roots have dried out. Roots must be moist at all times. Trees are moved either by the bare-root method or by the balled and burlapped (B&B) method. Bare-rooted trees may be moved if they are small and dormant. They should be protected by applying wet material such as peat moss to their roots immediately and keeping them moist. In the B&B method, balls of earth should be large enough to enclose the tree root system.

Figure 1



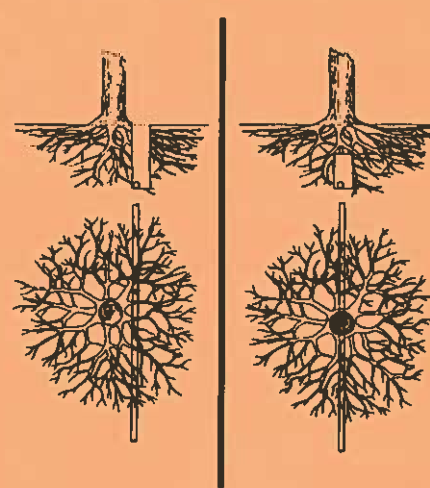
A tile system protects a tree from a raised grade. A, The tile is laid out on the original grade, leading from a dry well around the tree trunk. B, The tile system is covered with small stones to allow air to circulate over the root area.

Figure 2



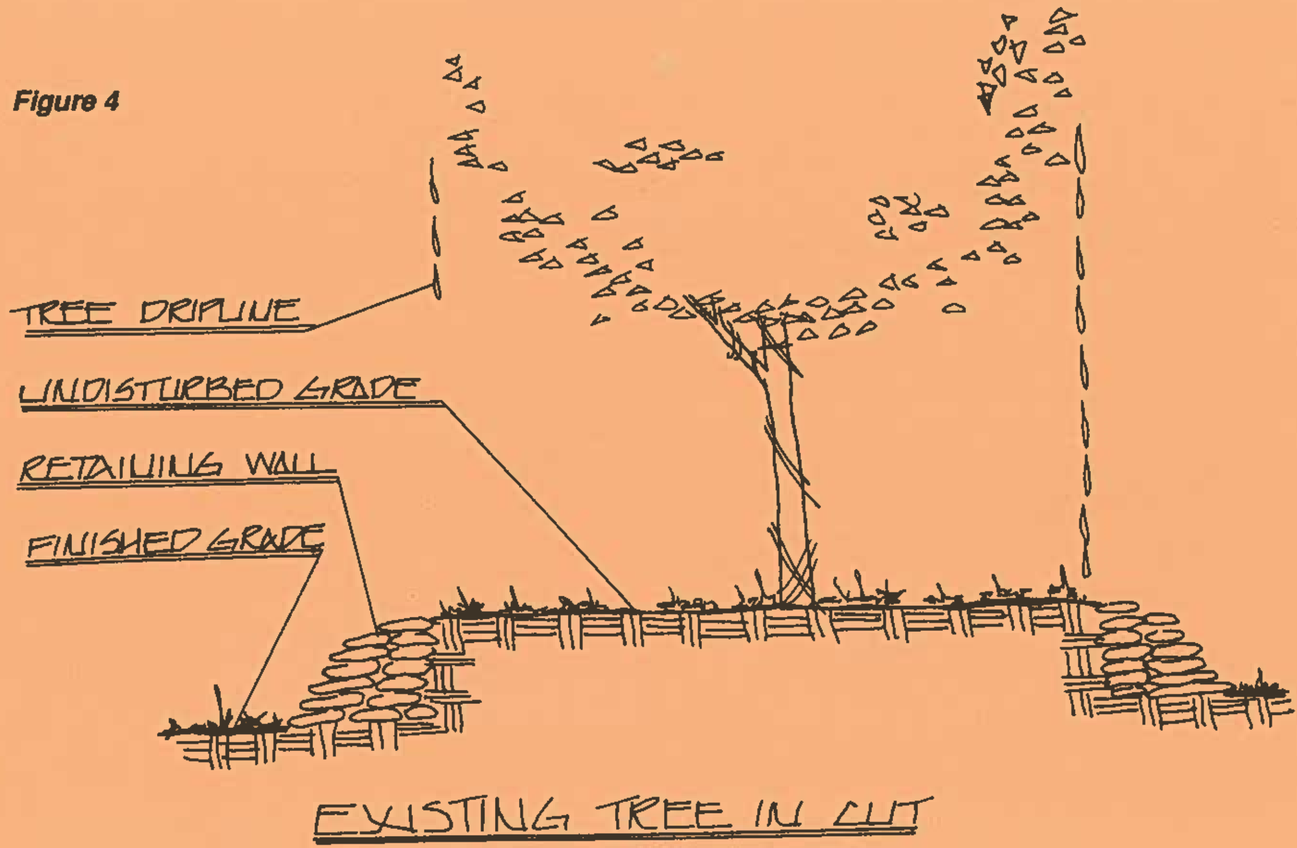
A retaining wall protects a tree from a lowered grade.

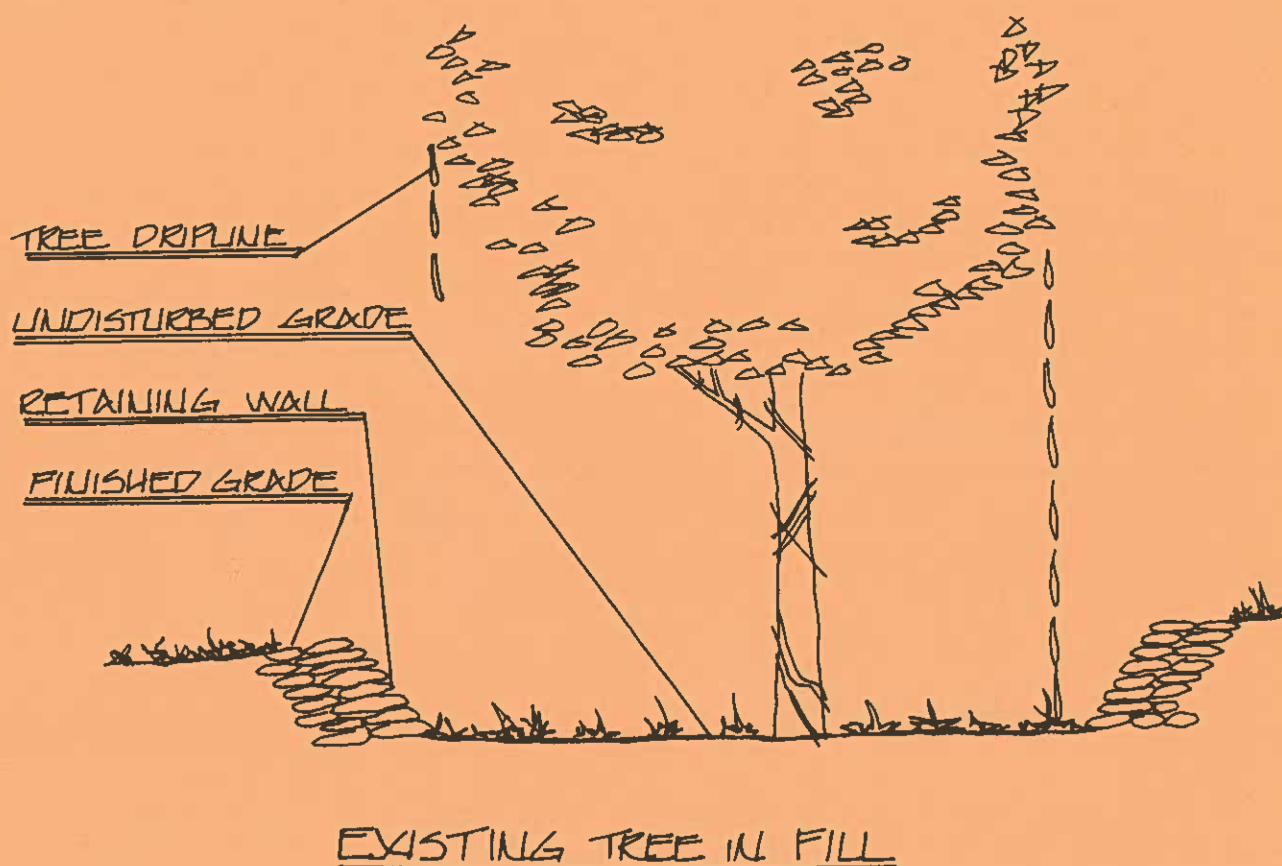
Figure 3



Tunnel beneath root systems. Drawings at left show trenching that would probably kill the tree. Drawings at right show how tunneling under the tree will preserve many of the important, feeder roots.

Figure 4


TREE DRIPLINE
UNDISTURBED GRADE
RETAINING WALL
FINISHED GRADE
EXISTING TREE IN CUT


TREE DRIPLINE
UNDISTURBED GRADE
RETAINING WALL
FINISHED GRADE
EXISTING TREE IN FILL

Selecting, Lifting, and Planting

During urban construction, it is often desirable to lift and transplant existing trees and shrubs on the site. This helps insure that the species are adapted to the area and usually reduces costs. Following are suggestions and guides on selection, lifting, planting, and care of these plants:

1. Selection of specimens of native plants for transplanting: Select young plants growing in full sun on a site similar to the intended planting site.

   a. Young plants are more satisfactory for transplanting than old plants.

   b. Nursery stock is more suitable for transplanting than natural-grown specimens.

2. Time of planting and method of digging:

   a. Transplant trees and shrubs during the dormant season.

   (1) Most small deciduous plants can be moved bare rooted.

   (a) Dig plants carefully with a sharp spade. Begin far enough away from the plant to save most of the fibrous roots. Use a sharp axe to cut large roots with a slanting cut. Trim damaged roots and excessively long roots with a sharp knife.

   (b) Keep roots of plants moist. Cover with moss, sawdust, or other moist material until planted.

   (2) Large evergreens and large deciduous plants should be moved with a ball of earth. The size of the ball of earth depends upon species and the size of plants to be moved.

TABLE 7 — Guide for Lifting Balled Plants

Coniferous Evergreens		Shrubs & Small Trees		Shade Trees	
Height of Plant	Dia. of Ball	Height of Plant	Dia. of Ball	Dia. of Tree	Dia. of Ball
2'-3'	13"	18"-24"	11"	1-1/4"-1-1/2"	18"
2'-4'	15"	2'-3'	12"	1-1/2"-2"	22"
4'-5'	17"	3'-4'	14"	2"-2-1/2"	24"
5'-6'	19"	4'-5'	16"	2-1/2"-3"	28"
6'-7'	21"	5'-6'	18"	3"-3-1/2"	33"
7'-8'	24"	6'-7'	20"	3-1/2"-4"	38"
8'-9'	26"	7'-8'	22"	4"4-1/2"	43"
9'-10'	28"	8'-9'	24"	4"-5"	48"
10'-12'	31"	9'-10'	26"		
12'-24'	35"				

(a) To lift plants, the soil should be moist but not excessively wet. When soil is dry, water thoroughly at least 2 days before digging. Plants should not be lifted when soil is frozen.

(b) For dug stock where ball of earth is 16 inches in diameter or less, use a sharp spade, and cut straight down all around the plant. Break the ball of earth loose using the spade as a pry under one side.

(c) Protect dug stock from wind and keep moist by watering every 2 days until planted.

3. Planting:

a. Bare-rooted plants:

(1) Make holes large enough to accommodate the root system without cramping. Plants should be set as close as possible to the same depth as they grew originally.

(2) Plants should be planted 2 inches above the original ground line to allow for settlement in the planting pit.

(3) Water thoroughly when hole is half filled with soil. Allow soil to settle and finish filling the hole. Water until the hole is filled with soil.

b. Balled with burlap plants:

(1) Rototill or spade an area 5 times the diameter of the planting ball to a depth of about 12". If soil additives are necessary, add uniformly.

(2) Excavate a hole in the center of the prepared area no deeper than the depth of the ball. Set tree in center of hole so new root ball sits on solid ground. The upper surface of the ball should be level with the existing ground line.

(3) Cut wire or twine from around root ball and peel back burlap. Place tree so the trunk is plumb.

(4) Backfill with soil excavated from planting pit; gently pack soil to prevent air pockets. (Watering can sometimes be used to achieve the desired effect.) Rake soil even over the entire area. Cover with 2"-4" of mulch, leaving "breathing" room around trunk.

(5) Prune broken branches. Do not paint pruned areas.

(6) Do not cut central leader.

(7) Do not leave a rim or saucer around the trunk to hold water.

(8) Do not stake the tree unless planted in a high wind area. If staked, remove wire after one year.

(9) Do not wrap tree with protective tape.

(10) Do not fertilize tree.

(11) Water frequently during the first growing season.

Sodding

General

Sodding is the stabilization of a disturbed area by use of sod obtained from another area. This practice is most applicable where a quick, dense turf is required in the shortest possible time. Satisfactory establishment depends on ground preparation, the quality of the sod used, and the quality of sod placement. One other item is that new sod needs watering to get a good start, especially in hot weather.

On some waterways, establishing a protective cover may be done effectively using high quality grass sod.

Natural sod makes an instant lawn.

Sodding

Definition: Establishing perennial herbaceous vegetation on critical areas using sod.

Purpose: To stabilize the soil, control erosion, and reduce runoff to downstream areas.

Where Applicable: On disturbed areas resulting from many kinds of urban construction. Most applicable on areas where frequent runoff water is expected and cannot otherwise be controlled. Applicable where a quick cover of grasses and/or legumes is needed (where damage might occur before a seeded stand can be established).

Specifications

1. Preparation of the site will be the same as if seeding were planned. Needed grading will be completed on the area to be seeded. Stone will be removed.

2. Lime and fertilizer will be applied according to soil test requirements. In lieu of a soil test, figure lime rate 2 to 3 tons per acre (115/lbs. per 1,000 sq. ft.) and fertilizer rate of 1,000 pounds of 10-20-10 per acre (23 lbs. per 1,000 sq. ft.). Lime and fertilizer should be mixed with soil to a depth of 3 inches.

3. Types of sodding:

   a. All of the area may be sodded. Examples are: a small lawn, steep bank, outlets, and areas where heavy use is expected immediately. Use Kentucky bluegrass, creeping red fescue, or a mixture of these species with redtop.

b. Strip sodding: Outlets and gullies can be stabilized effectively using strips of sod and seeding in between the strips. In addition to Kentucky bluegrass, red fescue, and redtop, vigorous sod of tall fescue and reed canary grass can be used for sod strips at right angles to flow of water. Strips should be 2 to 6 feet apart, depending on site.

4. Placing sod:

a. Sod should be carefully placed and pressed together so it will be continuous without any voids between the pieces. Joints between the ends of strips should be staggered. The edge of the sod at the outer edges of all gutters should be sufficiently deep so that the surface water will flow over the sod and not underneath sod strips.

b. On gutter and channel sodding, the sod should be carefully placed in rows or strips at right angles to the centerline of the channel (i.e., at right angles to the direction of flow). On steep graded channels, each strip of sod should be staked with at least two stakes not more than 18 inches apart. The stakes should be wood and should be approximately 1/2 by 3/4 inch by 12 inches long. They should be driven flush with the top of the sod and with the flat side against the slope.

c. On slopes 3 to 1 or steeper and where the drainage area into a sod gutter or channel is one-half acre or larger, 2-inch poultry netting or woven wire should be staked in place on the surface of the sod. The netting and sod should be staked with at least two stakes not more than 18 inches apart.

d. The stakes should be wood and should be approximately 1/2 inch by 3/4 inch by 24 inches. They should be driven with the flat side against the slope and on an angle toward the slope. The netting should be stapled on the side of each stake within 2 inches of the top of the stake. The stake should then be driven flush with the top of the sod.

e. The sod should be tamped lightly or rolled after placing to ensure good contact between sod and underlying soil. Rolling should be perpendicular to the direction sod strips were laid. Watering should consist of a thorough soaking of the sod and of the sod bed to a depth of at least 4 inches. The sod should be maintained in a moist condition by watering for a period of 30 days.

Topsoiling

General

Topsoiling is obtaining soil material favorable for plant growth and spreading it over an area where vegetation is to be established. The soil may be salvaged from the area during the construction progress and stockpiled or obtained from an alternate site. Addition of topsoil to an area after construction is completed will improve the chances of establishing a dense, vigorous vegetative cover. On some areas, the addition of soil material is a requirement to obtain vigorous plant growth. Soil to be used for this purpose should have chemical tests made to determine its desirability for use.

Topsoil can be stockpiled for future use.

Spreading topsoil after completion of grading.

Topsoiling

Definition: Obtaining soil material favorable to plant growth from other places and spreading it over an area where vegetation is to be established.

Purpose: To improve the soil medium for plant growth on areas that are disturbed by construction or otherwise having inadequate vegetative cover.

Where Applicable: Adding topsoil to establish finished grades may be needed to shorten the time and reduce the care needed to establish protective cover on disturbed soil material.

1. This practice applies to areas where texture and structure of soil material exposed will not support establishment and maintenance of protective vegetative cover. Four to six inches of soil material should be spread over the area.

2. It applies on areas where rooting zone is too shallow to support vegetation. Amount of soil material required depends on the site.

3. On areas found to be toxic (excess pyritic material on surface), the amount of soil material added depends on the site.

Specifications

1. Topsoil (soil material favorable to plant growth) shall consist of friable surface soil reasonably free of grass, roots, weeds, sticks, stones, or other foreign material.

2. Topsoil material from the construction site should be stockpiled soon after the area has been cleared on a place (designated by the engineer) where it will not interfere with construction progress. Topsoil piles should be seeded to reduce erosion during the storage period.

3. Spreading topsoil material:

a. Bonding: After the areas to be topsoiled have been brought to grade, and immediately prior to dumping and spreading the topsoil, the subgrade shall be loosened by discing or scarifying to a depth of at least 2 inches to insure bonding of the topsoil and subsoil.

b. Spreading should be attempted when soil conditions are favorable for tillage (soil should not be wet or frozen).

c. On highly acid areas and areas deficient in plant nutrients (especially soil phosphorus), lime and fertilizer should be added prior to spreading soil material.

d. Spread topsoil uniformly over the designated area. The amount of smoothing after spreading depends on slope (the tendency on steep areas where topsoil is being spread is to smooth it too much with construction equipment).

e. Seed as soon as possible after the topsoil has been spread.

f. Lime and fertilizer should be applied as required and mixed by slightly scarifying the surface 2 inches deep.

g. Special attention should be given to maintaining established grades in waterway, outlets, diversions, areas around buildings, etc., during spreading of topsoil.

Lawn Seeding

General

Lawn seeding is the most common vegetative practice carried out in urban areas. Most home owners consider grass lawns for their beauty but fail to realize their value in preventing soil erosion. Several items must be considered if a high quality lawn is to be established. Some of these are type of soil, drainage, chemical analysis of soil, the use of the lawn, and type of equipment needed for seeding.

The seedbed for a lawn is being prepared.

Lawn Seeding

Definition: Establishment of a short, dense sod or turf.

Purpose: To stabilize an area around buildings or in parks and improve the appearance.

Where Applicable: Areas around buildings, public parks, and intensive play areas.

Specifications

1. ***Grading*** — The lawn should be graded properly so that it will be easy to mow. The land should be graded so water does not collect in puddles. For most building sites, underground outlets for downspouts should not be combined with foundation drains. Steep terraces should be avoided. Slopes should be kept as gentle as possible. On areas that must be filled in, the surface should be covered with four to six inches of fine soil material (top soil material if available). All rocks and stones that are near the surface should be removed.

2. ***Tillage*** — The area should be thoroughly tilled to a depth of four to six inches. Lime and fertilizer should be incorporated before the last tillage operation. The seedbed should be firm for seeding.

3. ***Liming*** — Lime should be added to correct the soil pH to between 6.0 and 6.5. It should be applied according to recommendations based on a soil test. If the test results are not available when the lime must be applied, apply three tons of ground limestone per acre (150 pounds per 1,000 square feet) and apply the balance when the test results are available. Lime for seedings should be mixed with the top six inches of soil during tillage prior to seeding.

   Ground limestone may not be the most economical form of lime available. For different liming materials, a rough guide for conversion is:

   75 pounds hydrated lime =
   100 pounds ground limestone
   50 pounds burned lime =
   100 pounds ground limestone

4. ***Fertilization*** — Fertilizer should be applied according to recommendations based on a soil test. If test results are not available when the fertilizer must be applied and incorporated, apply 100 to 150 pounds of 10-20-10 prior to seeding and apply the balance when the test results are available. Nitrogen applications should be split as much as practical, a minimum of once each in the spring and fall. If nitrogen can only be applied once a year, it should be applied as urea-formaldehyde, or sulfur-coated urea. Fertilizer for seedings should be mixed with the top six inches of soil during tillage prior to seeding.

5. ***Seeding Date*** — The best time to seed a lawn is August 15 to October 15, especially where weed problems exist. The next most favorable time is in the spring from March 1 to June 15.

6. ***Seeding Method*** — Seed may be sown in many different ways: drilled, dropped with a precision seeder, or broadcast with a cyclone seeder, fertilizer spreader, or hydroseeder. All equipment should be calibrated before use. Seed should be divided into two lots. The second lot should be seeded at right angles to the first. All seedbeds should be firm before seeding and packed or rolled after seeding. Mulch should be applied and anchored on all seedings.

7. **Species Selection** [1]

	Lbs. per [2] Acre
For Regular Lawns:	
Full Sun	
Kentucky Bluegrass	80
Red or Hard Fescue	20
Partial Shade	
Red or Hard Fescue	80
Kentucky Bluegrass	20
For Heavy Traffic or Low Maintenance Lawns:	
Full Sun	
Tall Fescue	100
Kentucky Bluegrass	40
Partial Shade	
Tall Fescue	100
Red or Hard Fescue	40
For Wet Lawns:	
Full Sun	
Tall Fescue	100
Partial Shade	
Rough-Stalked Bluegrass	100

[1] Use cultivars recommended by the West Virginia Agricultural Extension Service. Use turf type tall fescue cultivars, not 'Kentucky 31'.

[2] Rates — 2-3 pounds per 1,000 sq. ft. for regular and wet lawns. Rates — 3-4 pounds per 1,000 sq. ft. for heavy traffic lawns.

8. ***Mulching*** — Mulch all areas for temporary erosion control and moisture retention. Mulch may be straw or hay, wood fiber, or mulch netting. Apply straw or weed-free hay at two tons per acre (100 pounds per 1,000 square feet). Apply wood fiber at 1,000 to 2,000 pounds per acre (25 to 50 pounds per 1,000 square feet). Apply mulch netting according to manufacturers' recommendations.

9. ***Mulch Anchoring*** — Anchor all mulch to insure it stays in place. Straw or hay mulch may be anchored by an asphalt emulsion, chemical anchoring solution, mulch netting, or disc anchoring tool. Wood fiber mulch usually has a chemical anchoring solution mixed with it. Mulch netting is stapled in place with metal staples. Asphalt emulsion is applied at a rate of 150 to 200 gallons per acre (4 to 5 gallons per 1,000 square feet).

10. ***Watering*** — Frequent light watering will aid the emergence of new grass seedings. Watering should stop when runoff begins. Once established, a grass stand will require an inch a week to maintain its vigor. Rainfall should be supplemented by watering until the stand is well established.

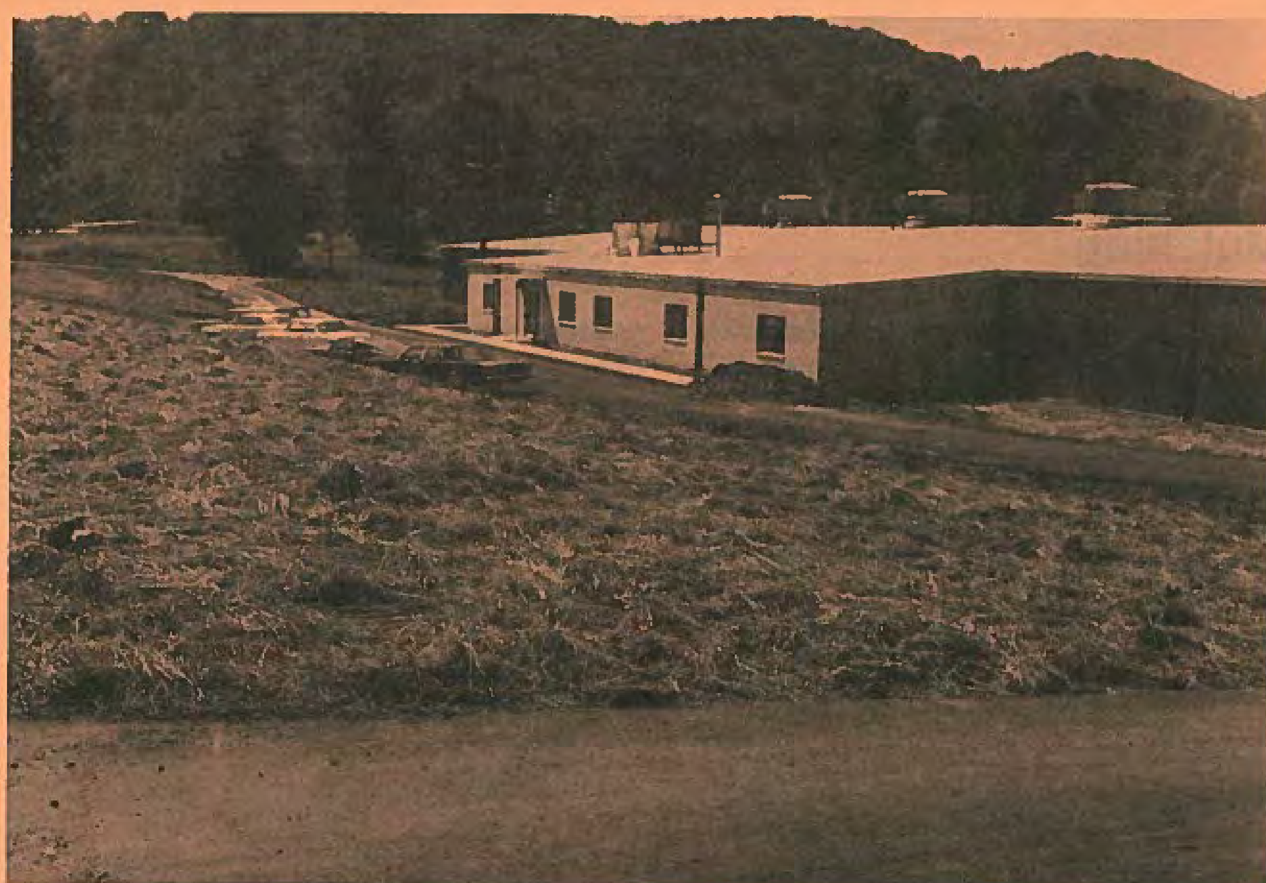
11. ***Mowing*** — Mow new grass stands to two inches when they are three inches tall. Fall seeded lawns may not need mowing until the following spring.

12. ***Maintenance*** — Lime and fertilize according to soil test. Split nitrogen applications as much as practical, with a minimum of one each in the spring and the fall. If only one application of nitrogen can be made, use a slow release source of nitrogen such as urea-formaldehyde, sulfur-coated urea, or IBDU. Irrigate in the spring and fall to supplement rainfall to provide an inch per week. Cool season grasses go dormant in the summer and do not need frequent mowing or irrigation. Mow grass so no more than one-third of the height is removed in one mowing. Mowing to two inches when the grass is three inches is ideal for most lawn species.

Mulching

General

Mulching consists of the application of materials such as straw, hay, wood chips, or shredded bark to the soil surface to conserve moisture, prevent surface compaction or crusting, control weeds, and help protect the site from erosion. Mulch can be applied alone to help prevent soil erosion during times when weather conditions do not permit seeding with temporary or permanent vegetation. Mulch is also recommended for use as a step in the overall seeding process. A properly applied mulch reduces soil erosion by protecting the soil surface, slows the rate of surface runoff, and increases the infiltration rate of the soil. This protection greatly improves the chances of seeds to germinate and grow.



This mulching was applied on a seeding around an industrial plant.

A plastic netting is placed in a waterway to anchor straw mulch.

Mulching

Definition: Application of plant residues or other suitable materials, not produced on the site, to the surface of the soil.

Purpose: To conserve moisture, prevent surface compaction or crusting, reduce runoff and erosion, and control weeds.

Where Applicable: On severely eroded areas, on disturbed areas such as newly constructed dams, outlets, waterways, and channel banks. Includes all cuts and fills resulting from construction. It is applicable as a temporary erosion control measure without seeding and on seeded areas.

Specifications

Mulch Rates and Length Limits for Construction Slopes

Mulching Material	Mulch Rate (Tons/Ac)	Land Slope (Percent)	Length Limit (Feet)
Straw or hay,	1.5	1-5	300
tied down by	1.5	6-10	150
anchoring and	2.0	1-5	400
tacking	2.0	6-10	200
equipment	2.0	11-15	150
	2.0	16-20	100
	2.0	21-25	75
	2.0	26-33	50
	2.0	34-50	35

Mulching Material

	Mulch Rate (Tons/Ac)	Land Slope (Percent)	Length Limit (Feet)
Crushed Stone,	135	< 16	200
1/4 to 1-1/2 in.	135	16-20	150
	135	21-33	100
	135	34-50	75
	240	< 21	300
	240	21-33	200
	240	34-50	150
Wood Chips	7	< 16	75
	7	16-20	50
	12	< 16	150
	12	16-20	100
	12	21-33	75
	25	< 16	200
	25	16-20	150
	25	21-33	100
	25	34-50	75

NOTE: Maximum slope length for which the specified mulch rate is considered effective. When this limit is exceeded, either a higher application rate or mechanical shortening of the effective slope length is required.

1. Types of mulch:

   a. Straw or hay — 1-1/2 to 2 tons per acre with seeding. 3 tons per acre used alone.
   b. Wood fiber — 1,000 to 2,000 pounds per acre.
   c. Mulch netting with excelsior, straw, coconut hair, nylon, or paper woven onto it. Use for waterways, areas subject to wind, or areas where other mulches are not available.
   d. Crushed stone — 135 to 240 tons per acre.
   e. Wood chips — 7 to 25 tons per acre.

2. Types of mulch anchoring:

   a. Straw or hay mulch

      (1) Asphalt emulsion sprayed on at 100 to 150 gallons per acre.
      (2) Chemical anchoring solution sprayed on at manufacturer's recommendation.
      (3) Mulch netting of plastic or jute stapled in place.
      (4) Mulch anchoring tool.

   b. Wood fiber mulch

      (1) Chemical anchoring solution sprayed on at manufacturer's recommendation.

   c. Mulch netting

      (1) Staples installed at manufacturer's recommendation.

   d. Crushed stone
   e. Wood chip

3. Types of application equipment:

   a. straw or hay mulch — mulch blower or by hand.
   b. wood fiber mulch — hydroseeder.
   c. mulch netting — by hand.
   d. crushed stone — by hand.
   e. wood chips — by hand

Erosion Control Mat

Definition: Application of a permanent erosion control blanket to the surface of the soil.

Purpose: To provide erosion control on areas that are subject to concentrated flows. To provide protection against the erosive flow of water and permit establishment of vegetation.

Where Applicable: On severely eroded areas, steep slopes, waterways, and ditches. On areas where velocity of flow is too great to establish vegetation, and where riprap or other paving is unnecessary or unacceptable.

Specifications

Material: Erosion control mat is a three dimensional multi-layered structure of polyethylene, nylon, vinyl, or other material specifically manufactured and recommended by the manufacturer for erosion control applications. Matting should be resistant to temperature extremes, high and low pH, ultraviolet radiation. It should be flexible enough to conform to depressions and uneven surfaces without being undermined.

Installation: Erosion control mat should be installed in accordance with the manufacturers recommendations. The general installation procedure is as follows:

1. Divert runoff away from the application area to the extent feasible.

2. Prepare a smooth surface by removing all vegetation, roots, tree stumps, rocks, and debris.

3. Fill holes and depressions. Grade and compact the entire area.

4. Prepare the seedbed; lime, fertilize, and seed before laying the mat.

   As an alternative, the mat may be installed and covered with approximately one inch of topsoil before seed is applied.

5. Install the mat in the direction of water flow, making sure that it is in constant contact with the ground.

6. Overlap each piece approximately three inches and secure with stakes or staples in accordance with manufacturers recommendations.

7. Bury the mat in trenches constructed perpendicular to the direction of flow at about twenty five foot intervals.

8. Bury the edge and ends of mats as recommended by the manufacturer.

Filter Strip

Definition: A strip or area of vegetation for removing sediment and other pollutants from runoff.

Purpose: To remove sediment and other pollutants from runoff by filtration, deposition, infiltration, absorption, adsorption, decomposition, and volatilization, thereby reducing pollution and protecting the environment.

Conditions Where Practice Applies: This practice applies at the lower edge of disturbed areas or above structural measures such as waterways and diversions, or adjacent to streams, ponds, and lakes.

Planning Considerations: Type and quantity of pollution must be determined. Slopes, soils, vegetative species, construction timing, need for irrigation, method of operation and maintenance must be considered. If the vegetated filter has outlet flow, it must be nonerosive.

Design Criteria

General: A soils report prepared by a qualified person shall be part of the documentation attesting to the feasibility of the vegetated filter system.

Grass species shall be such that the grass stems will remain upright during any design flow. For flow depths of .1 ft or less use n = 0.04. Where flow will be up to .5 ft, use n = 0.07.

Vegetation and Protection: Seedbed preparation and seeding shall be in accordance with the standard for Critical Area Planting. The type of vegetation shall be specified on the plans.

Fences will be installed around filter strips where it is necessary to prevent damage caused by livestock or other use.

Filter strips shall have a flow length of at least 10 ft for slopes less than 1 percent. Flow length shall increase proportionally up to a minimum of 33 ft for 30 percent slopes.

Specifications

All trees, stumps, roots, rocks, brush, and similar materials that can interfere with installing the vegetated filter shall be removed. The materials shall be disposed of in a manner that is consistent with the surrounding environment and with proper functioning of the vegetated filter.

When required, the filter shall be shaped to the grade and dimensions shown on the plan or as staked in the field. Topsoil shall be stockpiled and spread to the required grade and thickness. Excess spoil shall be disposed of in areas where it does not interfere with the required flow characteristics of the vegetated filter.

Construction operations shall be carried out in such a manner and sequence that erosion and air and water pollution will be minimized and held within legal limits. All disturbed areas will be graded smooth and blend with the surrounding ground, prior to seeding operations.

A protective cover of vegetation shall be established on all exposed surfaces of the filter strip and spoil areas. Lime and fertilizer will be spread at the rate shown on the drawings and will be disked into the soil to a depth of 4 inches to prepare a seedbed. Seed and mulch will be spread at the rate shown on the drawings. Where soil or climatic conditions preclude the use of vegetation and protection is needed, nonvegetative means such as mulches or gravel may be used. In some cases, temporary vegetation may be used until conditions are right for establishment of permanent vegetation. When required, the filter strip shall be fenced, as shown on the drawings, to protect the vegetation.

Maintaining Vegetative Measures

Maintenance of a vigorous plant cover insures proper protection along with improving the appearance of the area.

Maintenance activities should be planned as preventive treatment to avoid more serious problems later. These activities should occur on a regular basis consistent with favorable plant growth, weather, and use of the vegetation.

Common considerations for maintenance of vegetation are:

1. Make repair consisting of reseeding and/or mulching on small areas where vegetation is not satisfactory. Regular attention to small areas will save larger costs later.

2. Mowing frequency will depend on the location and use of the area, but mowing will be done frequently enough to control weeds and unwanted woody plants. The maximum amount depends on whether a short, dense turf is to be maintained. The type of equipment used is determined by the individual area. The mower should be sharp and operating properly so that vegetation is cut cleanly and not bruised excessively. Mowing height depends on grass species present, and frequency of mowing depends on the height of vegetation desired and rate of growth. Special attention is needed for herbaceous vegetation in outlets, waterways, and turf areas such as lawns and playgrounds.

3. New vegetation needs extra fertilization the first 2 or 3 years after establishment to maintain the desired plant density and improve the general vigor of the stand. Newly seeded areas need nitrogen fertilizer the first year after seeding. The phosphorus level should be maintained at medium to high levels, which means annual treatment on turf grass area and less frequent applications on areas with less intensive use. Limestone should be added as the need is indicated by soil tests made every 3 or 4 years.

4. Herbicides should be used as directed by local recommendations on those areas subject to the invasion of woody plants and weeds.

5. Dry vegetation and brush should be disposed of as this material detracts from appearance and is detrimental to the continued growth of established vegetation.

Section 4
Structural Measures — Permanent

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Structural Measures

Structural measures are used where vegetative measures are not adequate to prevent erosion, or where control of runoff is required to protect a facility or area of use. Structural measures are engineering practices which require careful planning, design, and installation to function as intended and be effective soil erosion control structures. Designs are based on many factors, including expected storm runoff, hazard to life and property should the structure fail, expected sediment accumulation, future land use, and maximum allowable water velocity. General information, design criteria and aids, and construction specifications are included in the following discussion of each practice.

Federal, State, and Local Laws

All federal, state, and local laws, rules, and regulations governing water use, pollution abatement, health, and safety shall be followed. The owner or operator shall be responsible for securing all required permits or approvals and for performing in accordance with such laws and regulations.

Permits may be required from the following agencies:

1. U.S. Army Corps of Engineers
2. West Virginia Department of Natural Resources
3. West Virginia Public Lands Corporation

Embankments for nonagricultural use that will be 6 feet or more in height, measured from the stream bottom at the downstream toe and that will or can impound 50 acre-feet or more of water will require that the owner submit an application for a certificate of approval. Embankments that will be 25 feet or more in height and that will or can impound 15 acre-feet or more of water will require that the owner submit an application for a certificate of approval from the state.

A lined waterway provides a safe outlet.

Land Grading and Shaping

Definition: This practice alters the surface of the ground to provide for better utilization, improvement of drainage, and erosion control. Large areas with steep slopes are easily graded with modern construction equipment. Land grading and shaping is common to virtually every construction site in West Virginia. This practice requires a well developed plan utilizing engineering surveys and investigations.

Purpose: To permit effective use of the land area for residential and industrial development, other related urban uses, improve surface drainage, and/or control erosion.

Conditions Where Practice Applies: On sites where surface irregularities, slopes, kinds of soil, obstructions, or wetness interfere with planned use; or where such use requires designed land surfaces. Facility sites requiring land grading or shaping may include building areas, playgrounds, parking areas, campsites, etc., and may include areas to be stabilized by surfacing or establishment of vegetation.

Special attention shall be given to maintaining or improving habitat for fish and wildlife where applicable.

Planning Considerations

Water Quantity: Effects of grading on quantity of runoff and surface storage must be considered. Yield of runoff will be increased by removal of vegetation and removal of surface storage areas.

Water Quality

1. Water quality will be effected by an increased rate of erosion during construction. The sediment yield will vary with changes in runoff. Factors to consider are the slope of the land before and after grading, the results caused by the construction process, and the amount of vegetation reestablished on the graded or shaped site.

2. Ground water quality will be affected by decreased loading of dissolved pollutants, particularly the dissolved nutrients from decaying surface residues.

3. Increased land usage and/or activities will have an effect on the quality of both surface and ground water.

Design Criteria

The grading plan shall be based on adequate surveys and investigations. The plan shall show location, slope, and elevation of surfaces to be graded and drainage practices and diversions required. It shall include location and magnitude of 'cuts' and 'fills' where exact finished grades are required. Practices where land grading and shaping are typically required include waterways, lined ditches, diversions, sediment basins, grade stabilization structures, retaining walls, and surface and subsurface drainage.

Shaping: If only shaping is required, the cuts and fills may be estimated by observation or by a minimum amount of work with engineer's level.

Grading: If grading to uniform surfaces is required, the design shall be based on a complete topographic or grid survey.

Earthwork: Side slopes of fills and cuts to be vegetated shall be no steeper than 2h:1v. Design slopes should vary in accordance with the stability of the soil. Side slopes of cuts in rock or unerodible material may be at the angle of repose for the material.

All fills shall be compacted in accordance with the requirements of the facility.

The finished grade will be in accordance with the requirements of the facility. On most areas, the surface shall have a continuous slope without grade reversals to an outlet to facilitate drainage. The length and degree of designed slope shall be within limits suitable to the soil type without causing erosion or ponding.

Depth of grading shall be controlled to prevent undue exposure of, or cuts into, parent material.

Erosion control and drainage: The requirements for erosion control and surface and subsurface drainage shall be included in the erosion and sediment control plan.

Surface drainage, waterways, diversions, subsurface drains, and underground outlets shall meet the applicable federal, state, or local requirements for design and installation.

Safety and environmental considerations: Features to protect land users shall be planned, if appropriate. Excavations shall be far enough from adjacent properties to protect from erosion, sliding, settling, or cracking. No fill shall be placed where it can slide, wash, or flow onto adjacent properties. Neither shall fill be placed that would cause a channel bank to fail from loading, or create a blockage in the channel.

Vegetation: Disturbed areas shall be vegetated as soon as practicable after grading.

Operation and Maintenance

An operation and maintenance plan shall be developed for the area treated. The plan shall be provided to, and discussed with, the land operator. Items that should be considered in the plan are:

1. Periodic inspections.
2. Maintenance of the area by mowing or chemical weed control, where appropriate.
3. Repair of eroding areas.
4. Repair of settlement areas where stump holes were filled or buried vegetative waste has deteriorated.
5. Maintenance of vegetation, where required, by fertilization, liming, or reseeding.

Plans and Specifications

Plans and specifications for land grading and shaping shall describe, in detail, the requirements for applying the practice to achieve its intended purpose.

Specifications may be developed from the following construction specification guide.

Specifications

The land to be graded shall be cleared of excess vegetative matter and trash.

Surface soil shall be removed from the area to the depth shown on the drawings and stockpiled on the outer perimeter of the work area.

If required, the ground surface shall be plowed or disked prior to the grading or shaping operation.
Lift thickness, compaction, overfill allowance, and moisture content of the fill material shall be as described on the drawings.

All grading and shaping operations shall be done to the neat lines and grades shown on the drawings.

Construction shall be done in such a way that chemicals, fuels, lubricants, and waste materials will not pollute air and water. Erosion, air pollution, and water pollution shall be minimized and held within legal limits.

Construction methods and vegetative measures that prevent erosion and control sediment shall be used.

A protective cover of vegetation shall be established on all exposed surfaces where soil and climatic conditions permit. Lime and fertilizer shall be spread at the specified rate and shall be disked into the soil to a depth of 4 inches to prepare a seedbed. Seed and mulch shall be applied at the specified rate. In some cases, temporary vegetation may be used for protection until conditions are suitable for establishment of permanent vegetation.

Where soil or climatic conditions do not permit the establishment of vegetation, and protection is needed, nonvegetative means such as mulches or gravel may be used.

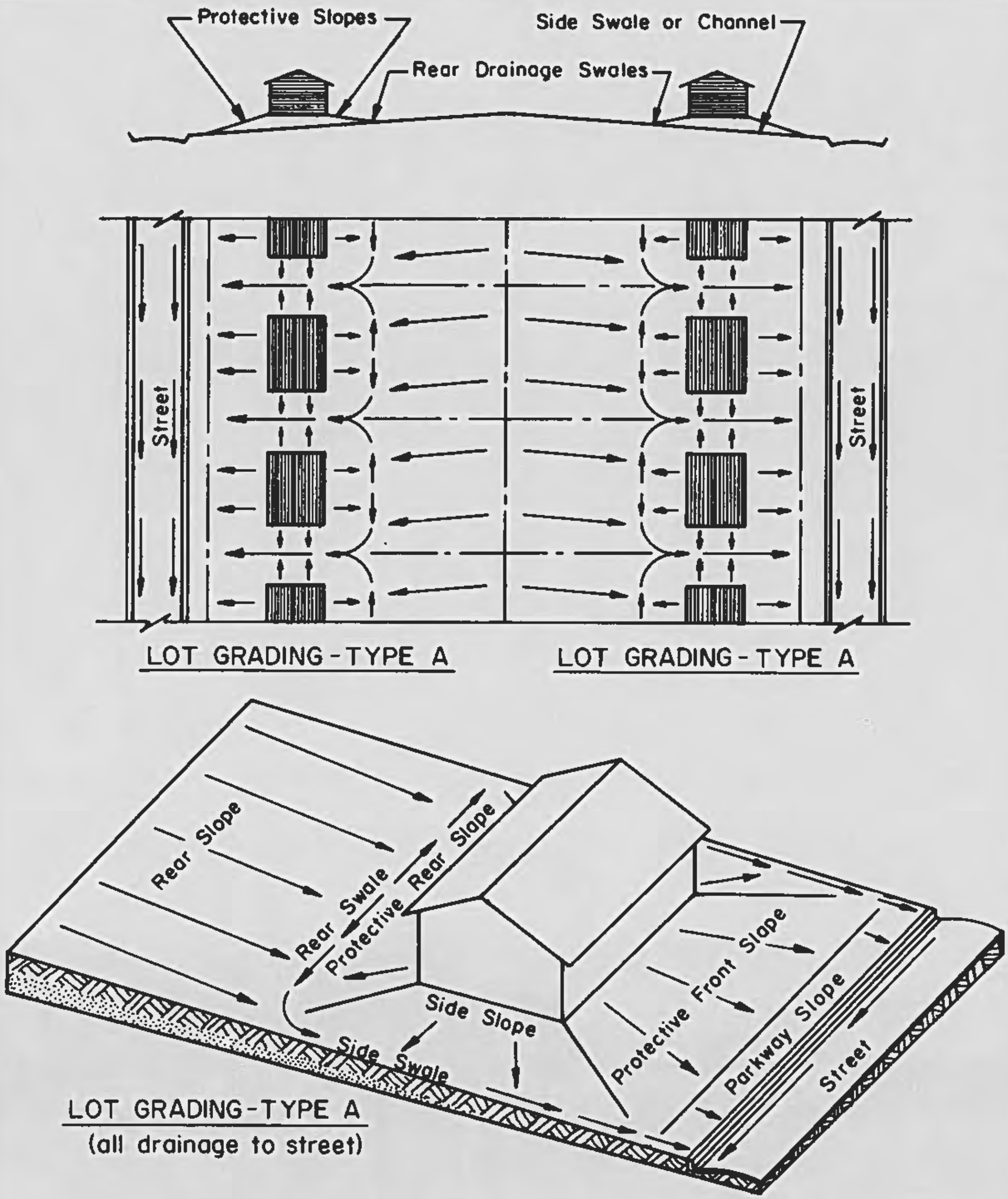
All work shall be done such that the installed practice gives a completed and finished appearance.

Design Aids

Figures 1 through 4 show examples of four types of grading for a block area under different topographic conditions.

A land-grading project for an elementary school is pictured near the completion stage.

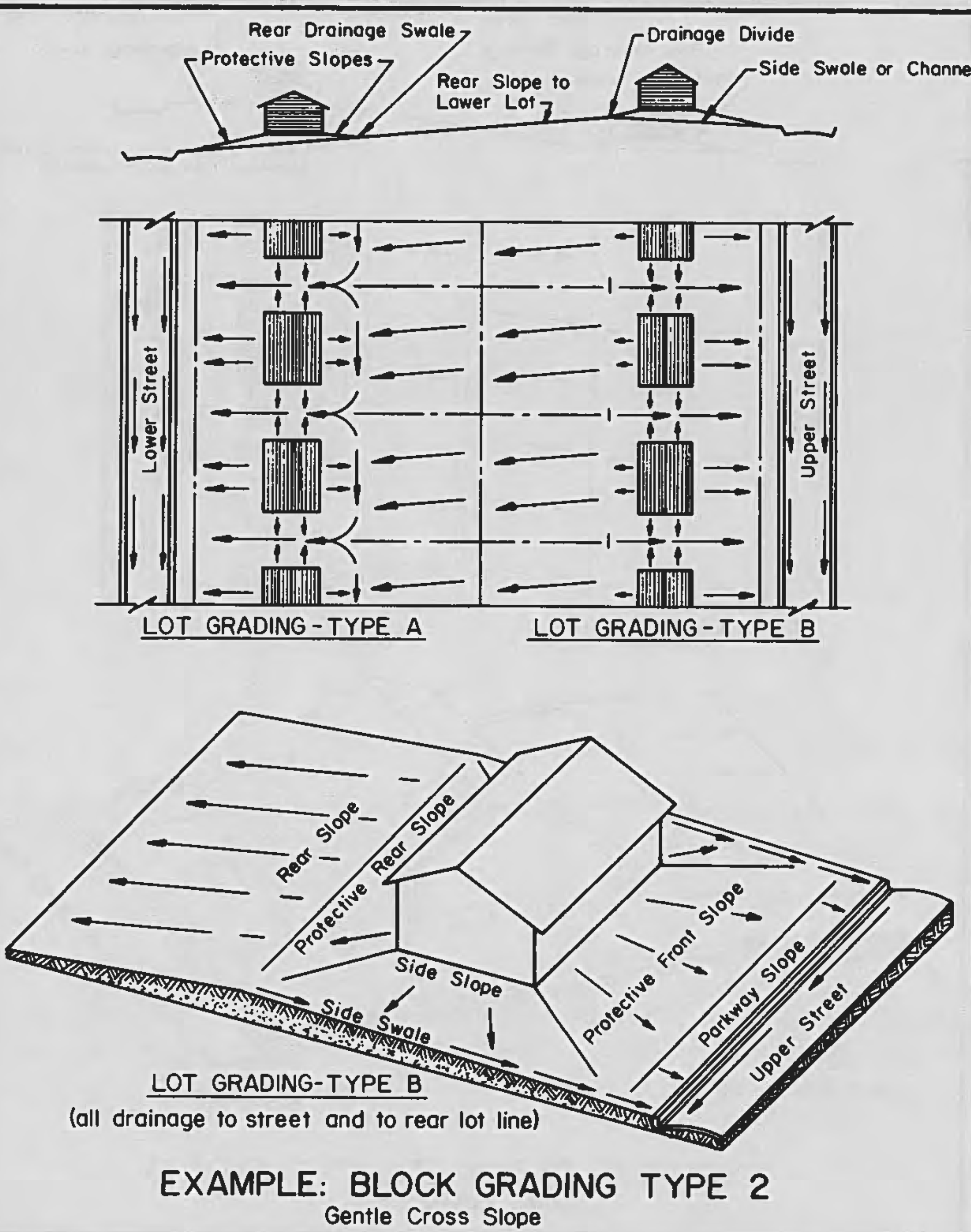
LAND GRADING—URBAN AREAS



EXAMPLE: BLOCK GRADING TYPE I
Ridge Along Rear Lot Lines

REFERENCE "Minimum Property Standards for One and Two Living Units" HUD-FHA November 1966 FHA No. 300	US DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE WEST VIRGINIA	**Figure 1**

LAND GRADING - URBAN AREAS

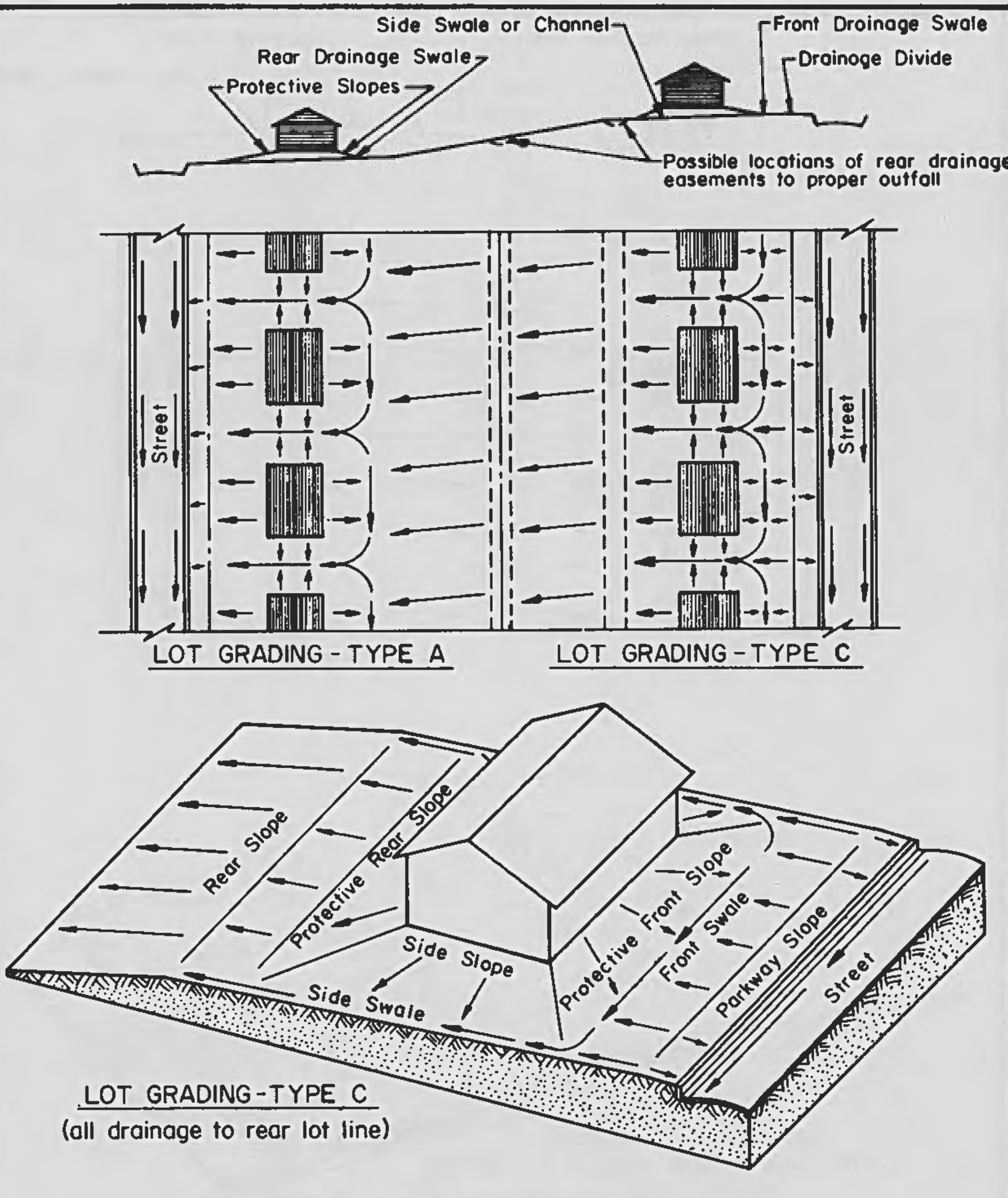


EXAMPLE: BLOCK GRADING TYPE 2

Gentle Cross Slope

REFERENCE "Minimum Property Standards for One and Two Living Units" HUD-FHA November 1966 FHA No. 300	US DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE WEST VIRGINIA	*Figure 2*

LAND GRADING – URBAN AREAS

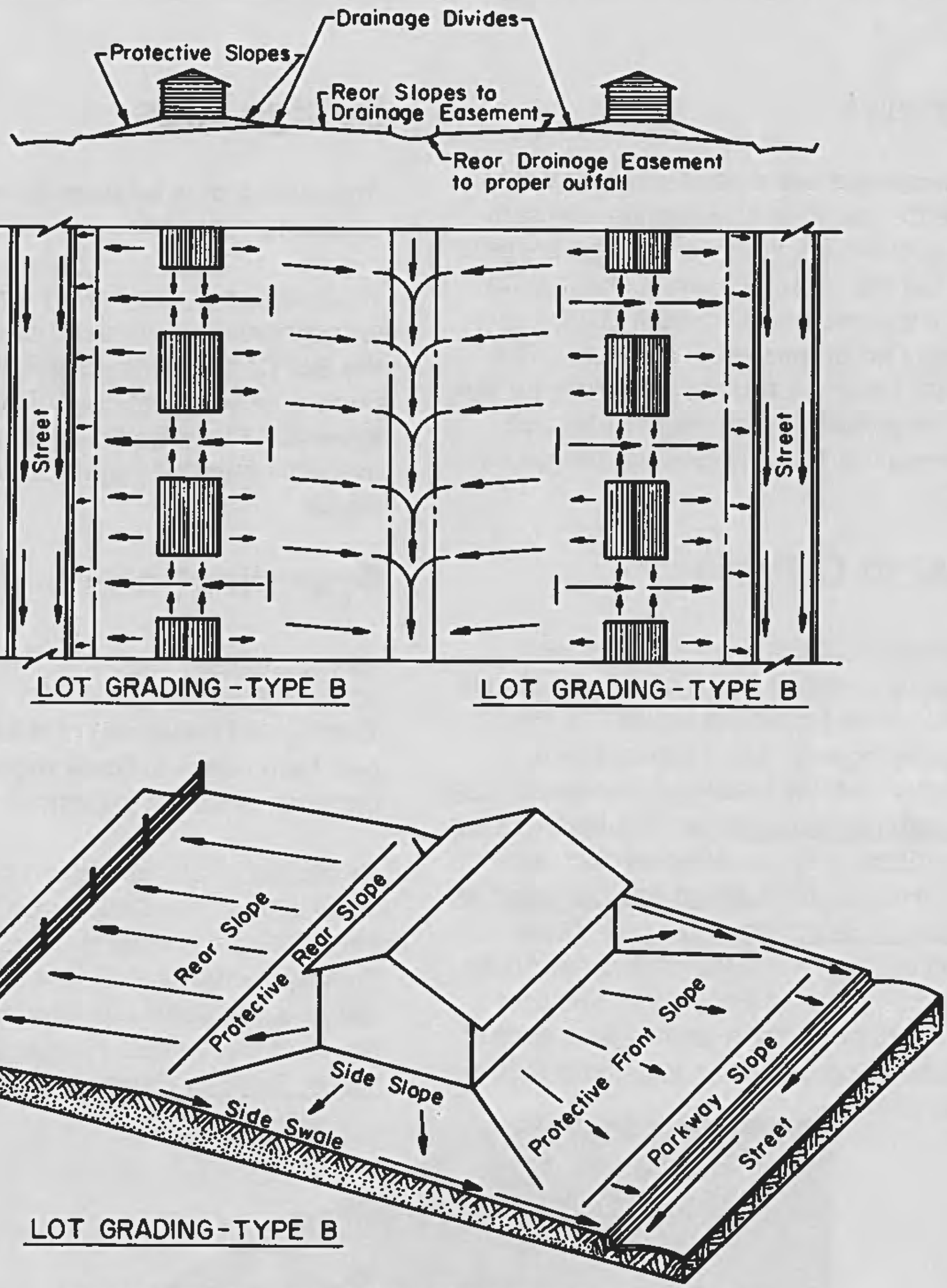


EXAMPLE: BLOCK GRADING TYPE 3

Steep Cross-Slope

REFERENCE "Minimum Property Standards for One and Two Living Units" HUD-FHA November 1966 FHA No. 300	US DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE WEST VIRGINIA	*Figure 3*

LAND GRADING - URBAN AREAS



EXAMPLE: BLOCK GRADING TYPE 4
Valley Along Rear Lot Lines

REFERENCE "Minimum Property Standards for One and Two Living Units" HUD-FHA November 1966 FHA No. 300	US DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE WEST VIRGINIA	*Figure 4*

Storm Sewers

General

Storm sewers are closed conduits which serve the purpose of collecting and conveying storm water from drainage areas to safe outlets. In urban areas, the installation of a storm sewer system is the basic element for proper water disposal. The system generally provides capacity for the safe disposal of storm water up to and including the 10-year, 24-hour frequency storm.

Design Criteria

The design criteria for storm sewers is generally specified by the city, town, or unit of government in whose jurisdiction the project is located. More information is available from the following references: Civil Engineering Handbook by Urquhart, Modern Sewer Design by the American Iron and Steel Institute, and Design and Construction of Sanitary Storm Sewers by the Water Pollution Control Federation and the American Society of Civil Engineers. The final layout and design of a storm sewer system should be approved by a registered professional engineer.

Design Aids

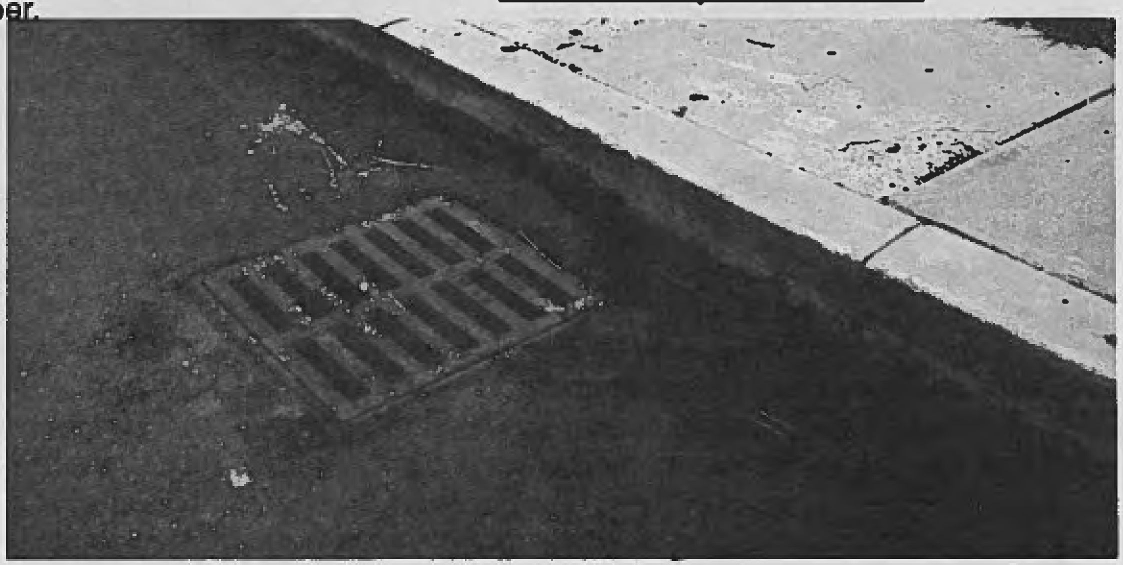
Appendix B may be used for estimating the runoff expected from a drainage area.

There are many hydrology aids available for estimating runoff such as Chapter 2 of the Soil Conservation Service Engineering Field Handbook and SCS Technical Release 55. Other guides and helps are available from the organizations listed above.

Specifications

All construction materials should meet applicable ASTM (American Society for Testing and Materials) or AASHTO (American Association of State Highway Transportation Officials) specifications.

Excavations, placement of conduits, backfilling, and other construction operations, should be performed in conformance with the requirements of OSHA (Occupational Safety and Health Act) and the requirements in the manual Design and Construction of Sanitary Storm Sewers.



Storm sewers are an integral part of urban development.

Diversions

Definition: A diversion consists of a channel or ridge, or a combination channel and ridge, constructed across sloping land either on the contour or at a predetermined grade. This practice diverts water from areas where it is in excess to sites where it can be used or disposed of safely. By diverting runoff, erosion damage to cut and fill slopes, construction sites, and other erodible areas is significantly reduced. Some flood protection for low- lying residences, businesses, parks, and other improvements may also be provided. Diversions are of two types, permanent and temporary.

Permanent diversions are those which will remain a part of the landscape and be maintained for the life of the practice.

Temporary diversions are installed to prevent serious erosion until other permanent measures can be installed. The life of a temporary diversion is usually less than one year.

Purpose: To divert excess water from one area for use or safe disposal in other areas.

Conditions where Practice Applies:
This practice applies to sites where:

1. Runoff damages urban areas and areas under construction.
2. Runoff is in excess and may be used or controlled by diverting to other sites.
3. An erosion and sediment control plan requires diversions as part of the pollution abatement scheme.
4. The length of slope should be reduced so that soil loss will not be excessive for the planned land use and treatment
5. Land slope is 20 percent or less, and slippage is not a problem.

Effects on Water Quantity and Quality

A diversion may increase the opportunity for surface water to infiltrate into the soil. This will be on a small percentage of the watershed. A diversion diverts surface water away from the area downslope from itself, reducing the opportunity for the water to infiltrate into the soil in this area. This is a much larger percentage of the watershed. The net effect may be the decrease in the amount of water infiltrating into the soil. Diversions may change the location in which surface water may flow, but they may have little effect on the quantity of surface or ground water.

This practice will assist in the stabilization of a watershed, resulting in the reduction of sheet and rill erosion by reducing the length of slope. Sediment may be reduced by the elimination of ephemeral and large gullies. This may reduce the amount of sediment and related pollutants delivered to the surface waters.

This practice diverts surface runoff away from particular areas and prevents the incorporation of any pollutants within these areas into the runoff and the transport of these pollutants to the receiving waters.

Design Criteria

Capacity: Diversions as temporary measures, with a life span of 1 year or less, shall carry as a minimum the 2-year, 24-

hour duration storm. Diversions that are part of an erosion and sediment control system designed to last more than 1 year must have the capacity to carry the peak runoff from a 10-year frequency, 24-hour duration storm as a minimum.

Permanent diversions designed to protect urban areas, buildings, and improved roads, shall have enough capacity to carry the peak runoff expected from a storm frequency consistent with the hazard involved but not less than a 25-year frequency, 24-hour duration storm with a freeboard not less than 0.3 ft.

Cross section: The channel may be parabolic, V-shaped, or trapezoidal. The diversion shall be designed to have stable side slopes. The ridge height shall include an adequate settlement factor. The ridge shall have a minimum top width of 4 feet at the design elevation. The minimum cross section shall meet the specified dimensions. The top of the constructed ridge shall not be lower at any point than the design elevation plus the specified overfill for settlement.

Grade and velocity: Channel grades may be uniform or variable. Channel velocity shall not exceed the velocity shown in Table 1.

Location: The location of the diversion shall be determined by outlet conditions, topography, cultural operations, and soil type.

Protection against sedimentation: Diversions should not be used below high-sediment-producing areas unless land treatment practices or structural measures, designed to prevent damaging accumulations of sediment in the channels, are installed with or before the diversions. If movement of sediment into the channel is a significant problem, a vegetated filter strip shall be used where soil or climate does not preclude its use. Then, the design shall include extra capacity for sediment and be supported by supplemental structures, cultural or tillage practices, or special maintenance measures.

Outlets: Each diversion must have a safe and stable outlet with adequate capacity. The outlet may be a grassed waterway, a vegetated or paved area, a grade stabilization structure, an underground outlet, a stable water-course, or a combination of these practices. The outlet must convey runoff to a point where outflow will not cause damage. Vegetative outlets shall be installed before diversion construction to insure establishment of vegetative cover in the outlet channel.

Underground outlets consist of an inlet and underground conduit. The release rate when combined with storage is to be such that the design storm will not overtop the diversion ridge.

The design elevation of the water surface in the diversion shall not be lower than the design elevation of the water surface in the outlet at their junction when both are operating at design flow.

Vegetation: Disturbed areas that are not to be cultivated shall be established to grass as soon as practicable after construction. If the soils or climatic conditions preclude the use of vegetation for erosion protection, nonvegetative linings such as gravel, rock rip-rap, or cellular block may be used. Seedbed preparation, seeding, fertilizing, and mulching shall comply with standards in the vegetation measures section of this handbook.

Operation and Maintenance

A maintenance program shall be established to maintain diversion capacity, storage, ridge height, and the outlets. Maintenance needs are to be discussed in the erosion and sediment control plan. As a minimum, the diversion must be inspected and repaired as necessary after every storm event that causes flow in the diversion. Any hazards must be brought to the attention of the responsible person.

Plans and Specifications

Plans and specifications for installing diversions shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose. See construction specification guide that follows.

Design Aids

Appendix B may be used for estimating the runoff expected from a drainage area. Other guides which may be used include Chapter 2 of the Soil Conservation Service Engineering Field Handbook and SCS Technical Release 55.

The design for capacity and stability may be calculated by Manning's equation by taking into consideration the degrees of retardance of various vegetal covers. Designs will normally be based on retardance "D" for stability and permissible velocity and retardance "C" for capacity (top width and depth). Design procedures are outlined in detail in Chapter 9, Engineering Field Handbook.

A series of temporary diversions are installed on a disturbed, steep slope to protect it from erosion until vegetation is established.

Table 1 — Permissible velocities for diversions.

	Permissible Velocity				
Soil Texture	Bare Channel	Retardance	Channel Poor	Vegetation Fair	Condition Good
	ft/s			ft/s	
Sand, silt, sandy loam, & silty loam	1.5	B	2.0	3.0	4.0
		C	1.5	2.5	3.5
		D	1.5	2.0	3.0
Silty clay loam & sandy clay loam	2.0	B	3.0	4.0	5.0
		C	2.5	3.5	4.5
		D	2.0	3.0	4.0
Clay	2.5	B	3.5	5.0	6.0
		C	3.0	4.5	5.5
		D	2.5	4.0	5.0
Coarse gravel	5.0	B, C, or D	5.0	6.0	7.0
Cobbles & shale	6.0	B, C, or D	6.0	7.0	8.0

Table 2 — Guide to selection of vegetal retardance.

Stand	Average length of vegetation	Degree of retardance	Stand	Average length of vegetation	Degree of retardance
	in			in	
Good	Longer than 30	A	Fair	Longer than 30	B
	11 to 24	B		11 to 24	C
	6 to 10	C		6 to 10	D
	2 to 6	D		2 to 6	D
	Less than 2	E		Less than 2	E

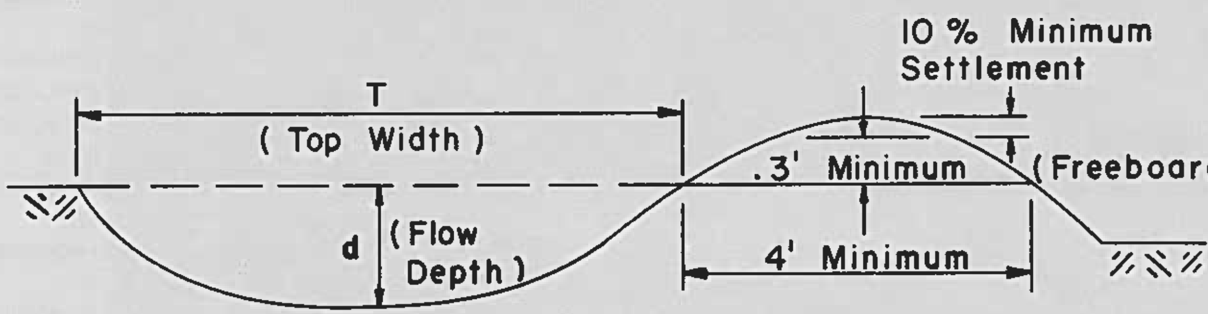


Figure 5 — Typical cross section of parabolic diversion

Specifications

Preparation of sites for diversion construction shall be done in a manner which destroys as little vegetation outside the areas to be occupied by the diversion as feasible. Special efforts shall be made to save trees of significant value.

Construction operations shall be carried out in a manner to minimize air and water pollution and hold such pollution within legal limits. Bare areas shall be vegetated as soon as practical after earthwork is completed.

Disposal of debris from site preparation shall be done in a manner as to cause minimum pollution to the environment.

All ditches or gullies to be crossed shall be filled before construction begins or as a part of construction. Fence rows or other obstructions that will interfere with the successful operation of the diversion shall be removed.

The earth materials used in constructing the earthfill portions of the diversions shall be obtained from the diversion channel or other approved sources.

The earthfill materials used to construct diversions shall be compacted by routing the construction equipment over the fill in such a manner that the entire surface of the fill will be traversed by not less than one tread track of the equipment.

When an excess of earth material results from cutting the channel cross section and grade, it shall be deposited adjacent to the supporting ridge or other approved area.

The completed diversion shall conform to the cross section, line, and grade shown on the design.

All sections of the channel shall be free-draining. Low spots shall not exceed 0.2 foot in depth, nor extend for more than 50 feet. No low spots are permissible on soils subject to slippage. All portions of the diversion shall be finished in such a manner that vegetative cover can be established.

A permanent diversion was constructed to protect a school from runoff.

Waterways

General

Waterways are natural drainage depressions or constructed channels used to convey runoff to stable outlets. These measures are generally installed in areas where flow occurs only during storm periods or where the base flow is carried by an underground conduit. A common use is to provide a safe outlet for diversions. They are designed to accommodate the expected runoff from a certain frequency storm without damage to the channel. Flow velocities determine the type of waterway lining needed, such as vegetative, concrete, riprap, or asphalt.

A grass waterway starts with land shaping.

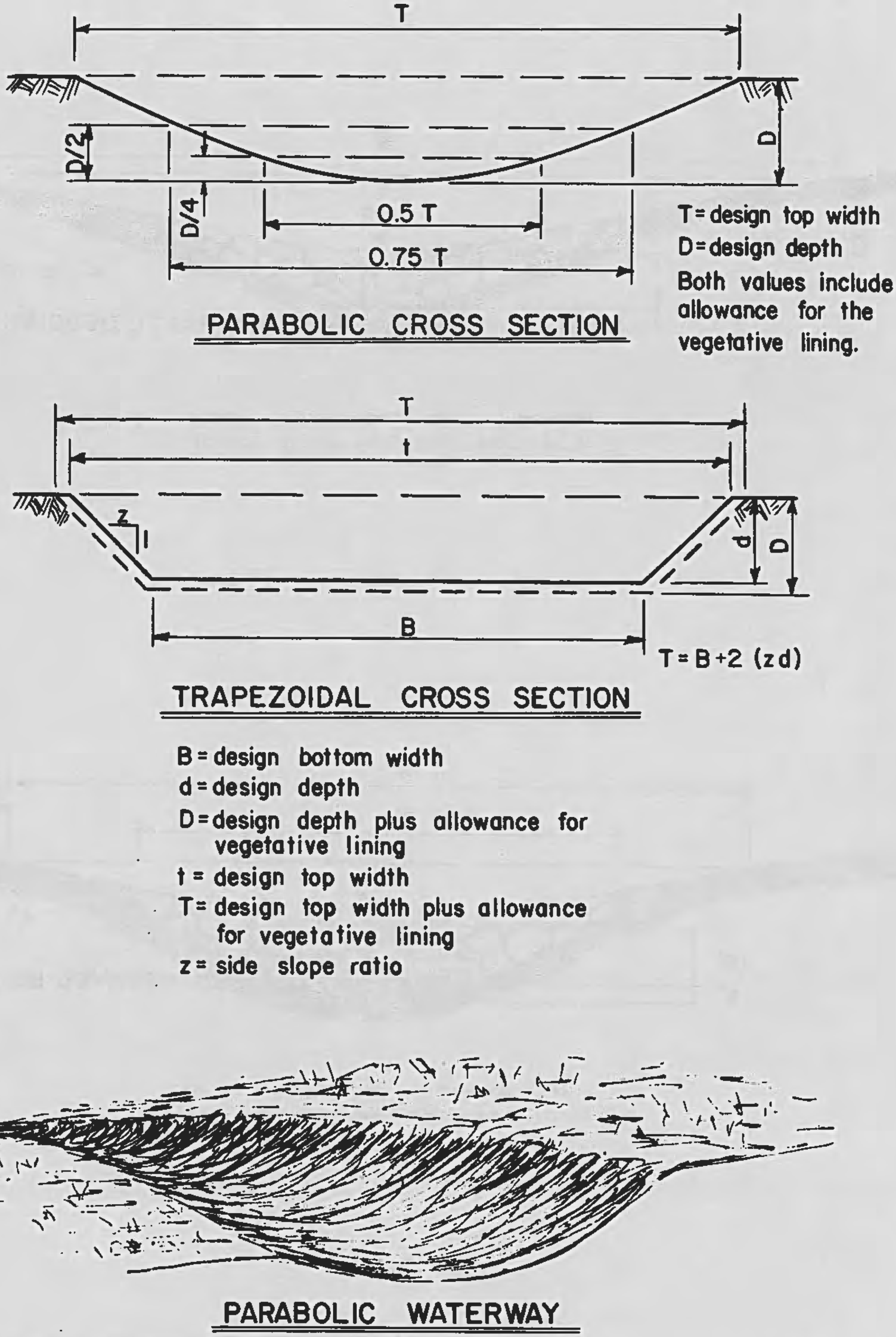
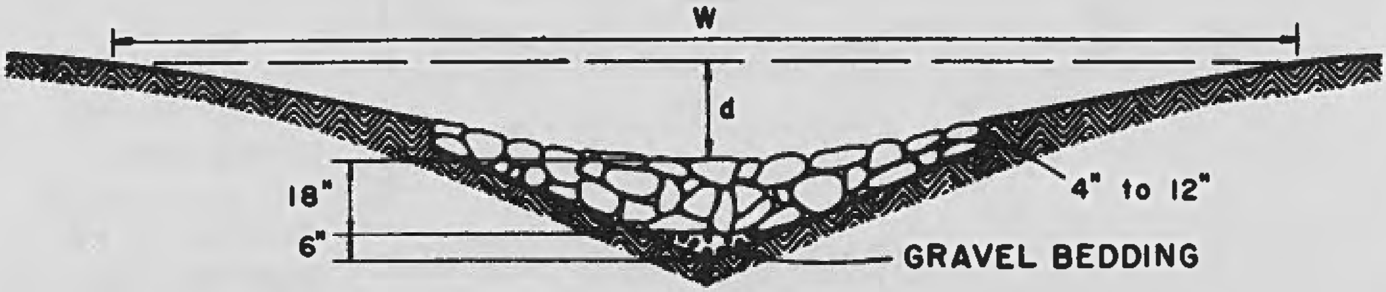
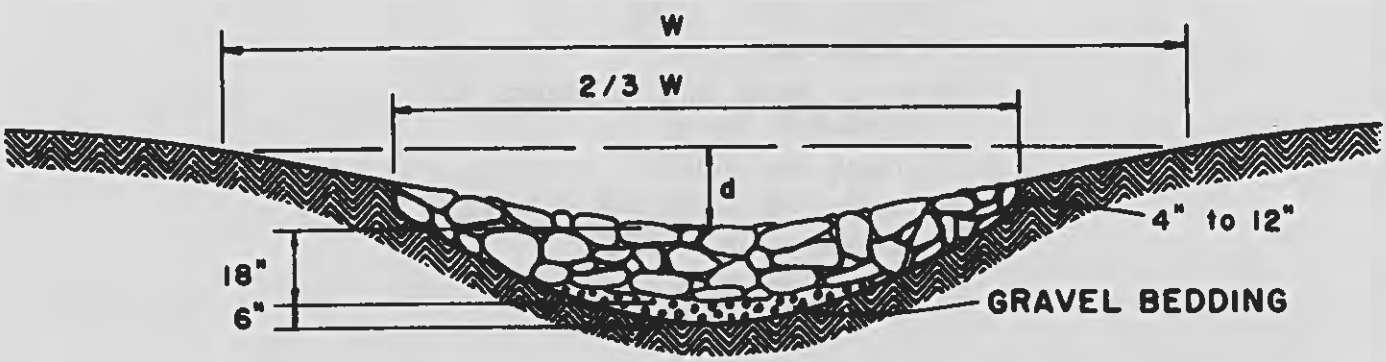


Figure 6 — Typical waterway cross sections



Waterway with stone center drain
V section shaped by motor patrol



Waterway with stone center drain
Rounded section shaped by bulldozer

Figure 7 — Waterway with stone center

Lined Waterway or Outlet

Definition: A waterway or outlet having an erosion-resistant lining of concrete, stone, or other permanent material. The lined section extends up the side slopes to a designed depth. The earth above the permanent lining may be vegetated or otherwise protected.

Purpose: To provide for safe disposal of runoff from other erosion and sediment control structures or from natural concentrations of flow, without damage by erosion or flooding, where unlined or grassed waterways would be inadequate. Properly designed linings may also control seepage, piping, and sloughing or slides.

Conditions where Practice Applies:
This practice applies if the following or similar conditions exist:

1. Concentrated runoff is such that a lining is needed to control erosion.

2. Steep grades, wetness, prolonged base flow, seepage, or piping would cause erosion.

3. The location is such that use by people or animals preclude use of vegetated waterways or outlets.

4. High-value property or adjacent facilities warrant the extra cost to contain design runoff in a limited space.

5. Soils are highly erosive or other soil or climatic conditions preclude using vegetation.

6. Installation of nonreinforced concrete or mortared flagstone linings, shall be made only on low shrink-swell soils that are well drained or where subgrade drainage facilities are installed.

Planning Considerations

Water Quantity

1. Effects upon components of the water budget, especially effects on volumes and rates of runoff, infiltration, evaporation transpiration, deep percolation, and ground water recharge should be considered.
2. Seasonal and climatic changes generally will have more effect than the presence or absence of the lined waterway.

Water Quality

1. Filtering effects of vegetation on the movement of sediment, and dissolved and sediment attached substances will be evaluated. Suspended pollutants may move more quickly to a receiving water body.

2. Effects on the visual quality of the water resources will be evaluated. Concentrated erosion may be controlled or eliminated by the practice installation.

3. Short-term and construction-related effects on the quality of water resources will be considered.

Design Criteria

This practice applies to waterways or outlets having linings of nonreinforced, cast in-place concrete; flagstone mortared in place; rock riprap; or similar permanent linings. This standard may also be used for grassed waterways with stone centers or small lined sections to carry prolonged low flows. The maximum capacity of the waterway flowing at the design depth shall not exceed 200 cubic feet per second. A lined outlet shall be adequate to carry the flow of the pipes or structures discharging into it.

Capacity: The minimum capacity shall be adequate to carry the peak rate of runoff from a 10-year frequency storm. In cases where a lined outlet is designed to carry flows from a structure, diversion, or any other water conveyance, the lined outlet shall be designed to convey the same peak flow as that structure, diversion, or conveyance without causing damage by erosion or flooding. Velocity shall be computed by using Manning's Formula with a coefficient of roughness "n" as follows:

Concrete	
Trowel Finish	.012 - .014
Float Finish	.013 - .017
Gunite	.016 - .022
Flagstone	.020 - .025
Masonry Units (block)	.030 - .050
Riprap	see Figure 8

Velocity: Maximum design velocity shall be as shown in Figure 11. Except for short transition sections, flow in the range of 0.7 to 1.3 of the critical slope must be avoided unless the channel is straight. Velocities exceeding critical shall be restricted to straight reaches. Waterways or outlets with velocities exceeding critical shall discharge into an energy dissipater to reduce velocity to less than critical.

Cross section: The cross section shall be triangular, parabolic, or trapezoidal. A cross section made of monolithic concrete may be rectangular.

Side slope: The steepest permissible side slopes, horizontal to vertical, shall be as follows:

Nonreinforced concrete:
Hand-placed formed concrete
Height of lining, 1.5 ft or less .. Vertical
Hand-placed concrete or mortared in place flagstone
Height of lining, less than 2 ft .... 1 to 1
Height of lining, more than 2 ft .. 2 to 1
Slip form concrete:
Height of lining, less than 3 ft .... 1 to 1
Rock riprap .... 2 to 1

Suggested Design Procedure for Riprap Lined Waterways:

1. For a given discharge, slope, and estimated d_{50} size, select a trial bottom width and side slope.

2. Estimate the depth of flow.

3. Determine Manning's "n" from Figure 8.

4. Compute the discharge capacity of the waterway for the estimated depth of flow using Manning's formula. See Figure 9 for the elements of channel sections.

5. If the computed discharge is less than the discharge used for the design, increase the depth of flow and repeat the procedure from step 3.

   If the computed discharge is greater than the discharge used for the design, decrease the depth of flow and repeat the procedure from step 3.

Repeat the procedure until the computed discharge equals the design discharge. The depth at which this occurs is the normal depth of flow for the waterway.

6. Compute the velocity of flow for the waterway using the design discharge and the cross-sectional area of flow at normal depth.
   ($V = Q / A$)

   Compare this velocity to the allowable velocity taken from Figure 10.

   If the computed velocity is less than the allowable velocity, the riprap is stable. If the computed velocity is also less than the maximum design velocity from Figure 11, the design is acceptable.

   If the computed velocity fails either of the above conditions, increase the channel width and/or the d50 size and repeat from step 2.

Lining Thickness: The minimum lining thickness shall be as follows:

Concrete	4 in. (If welded wire fabric reinforcing is used the minimum thickness shall be 5 in.
Rock riprap	Maximum stone size plus thickness of filter or bedding
Flagstone	4 in., including mortar bed

Extent of lining: The lining shall be used to protect the waterway or outlet to the point where the velocity is reduced below the maximum allowable for the soil type shown in table 3.

Freeboard: The minimum freeboard for lined waterways or outlets shall be 0.25 ft. above design high water in areas where erosion-resistant vegetation cannot be grown adjacent to the paved side slopes. No freeboard is required if vegetation can be grown and maintained.

Related structures: Side inlets, drop structures, and energy dissipaters shall meet the hydraulic and structural requirements for the site.

Filters or bedding: Filters or bedding shall be used to prevent piping. Drains shall be used to reduce uplift pressure and to collect water, as required. Filters, bedding, and drains shall be designed according to SCS standards. Weep holes may be used with drains if needed.

Concrete: Concrete used for lining shall be proportioned so that it is plastic enough for thorough consolidation and stiff enough to stay in place on side slopes. A dense durable product shall be required.

Specify a mix that can be certified as suitable to produce a minimum strength of at least 3,000 lb/in^2. Cement used shall be Portland cement, Types I, II, or if required, Types IV or V. Aggregate used shall have a maximum size of 1-1/2 inch.

Mortar: Mortar used for mortared in-place flagstone shall consist of a workable mix of cement, sand, and water with a water-cement ratio of not more than 6 gallons of water per bag of cement.

Contraction joints: Contraction joints in concrete linings, if required, shall be formed transversely to a depth of about one-third the thickness of the lining at a uniform spacing in the range of 10 to 15 ft. Provide for uniform support to the joint to prevent unequal settlement.

Rock riprap or flagstone: Stone used for riprap shall be dense and hard enough to withstand exposure to air, water, freezing, and thawing. Riprap shall be reasonably well-graded between the specified minimum and maximum sizes. Maximum size shall be 1.5 times the d50 size. Minimum size shall be no less than 3 inches. Flagstone shall be flat for ease of placement and have the strength to resist exposure and breaking.

Operation and Maintenance

Provisions must be made for timely maintenance to insure lined waterways function properly. Items that should be considered are suggested below. These are not the only items that may need to be considered. Each plan must be site specific.

1. Inspect periodically, at least after every design frequency storm.
2. Repair blowouts, slumps, and eroded areas.
3. Regrade and reseed bare areas above the lining.
4. Replace riprap to design grade if settling or washing has occurred.
5. Inspect concrete for cracks, spalls, or damage needing repair.
6. Remove debris from channel.
7. Repair flagstones or hand-laid rock.

Plans and Specifications

Plans and specifications for constructing lined waterways or outlets shall describe the requirements for applying the practice to achieve its intended purposes.

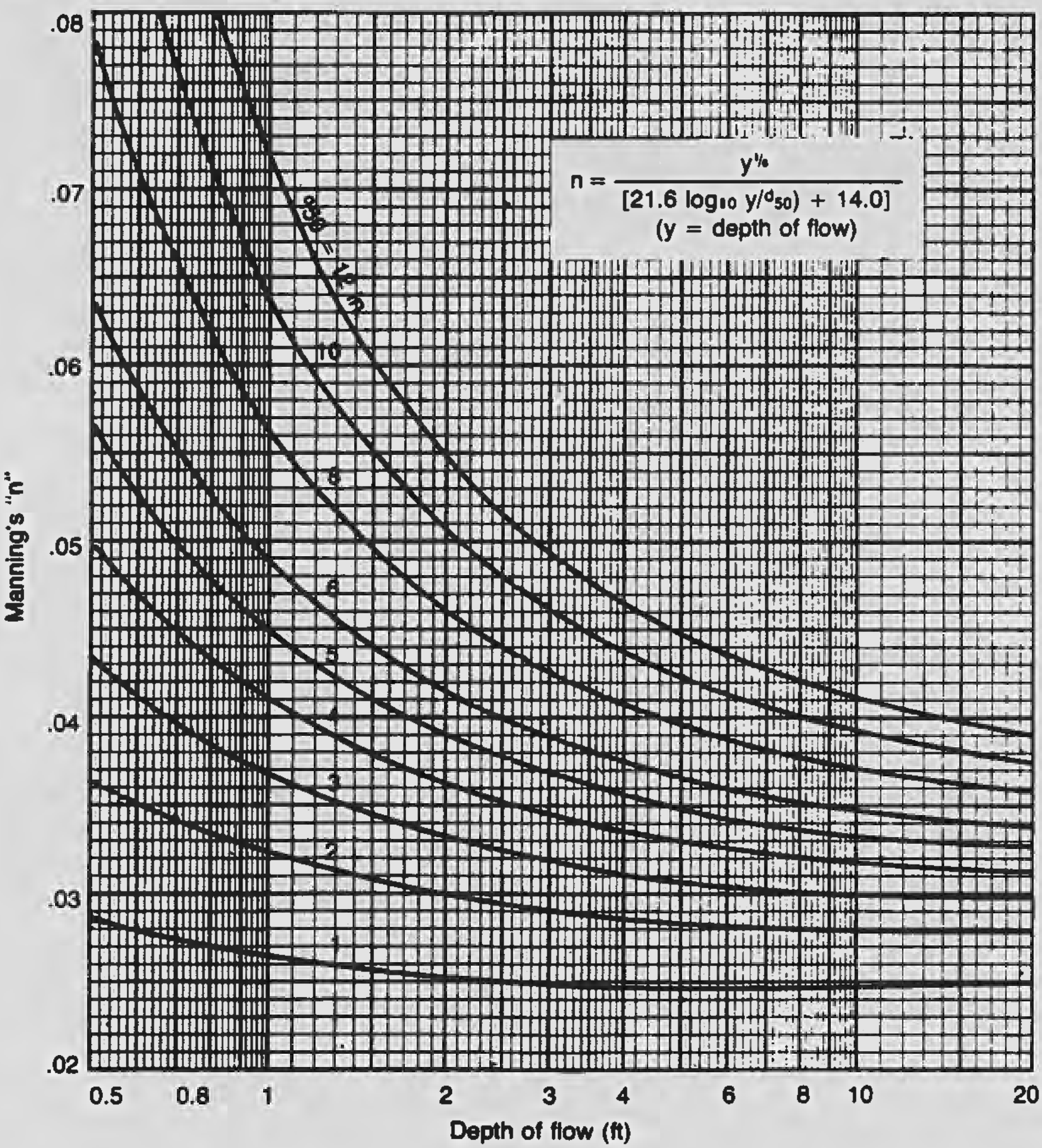
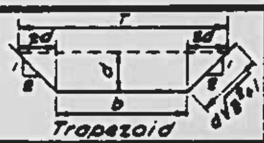
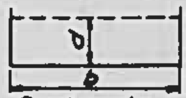
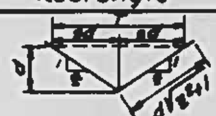
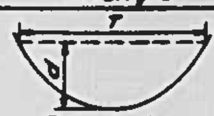


Figure 8 — Values of n for Riprap-Lined Channels, d_{50} Size vs Depth of Flow.

Section	Area a	Wetted Perimeter p	Hydraulic Radius r	Top Width T
 Trapezoid	$bd + zd^2$	$b + 2d\sqrt{z^2+1}$	$\frac{bd + zd^2}{b + 2d\sqrt{z^2+1}}$	$b + 2zd$
 Rectangle	bd	$b + 2d$	$\frac{bd}{b + 2d}$	b
 Triangle	zd^2	$2d\sqrt{z^2+1}$	$\frac{zd}{2\sqrt{z^2+1}}$	$2zd$
 Parabola	$\frac{2}{3}dT$	$T + \frac{8d^2}{3T}$ 1/	$\frac{2dT^2}{3T^2 + 8d^2}$ 1/	$\frac{3a}{2d}$

1/ Satisfactory approximation for the interval $0 < \frac{d}{T} \leq 0.25$
When $d/T > 0.25$, use $p = \frac{1}{2}\sqrt{16d^2 + T^2} + \frac{T^2}{8d}\sinh^{-1}\frac{4d}{T}$

Figure 9 — Elements of Channel Sections

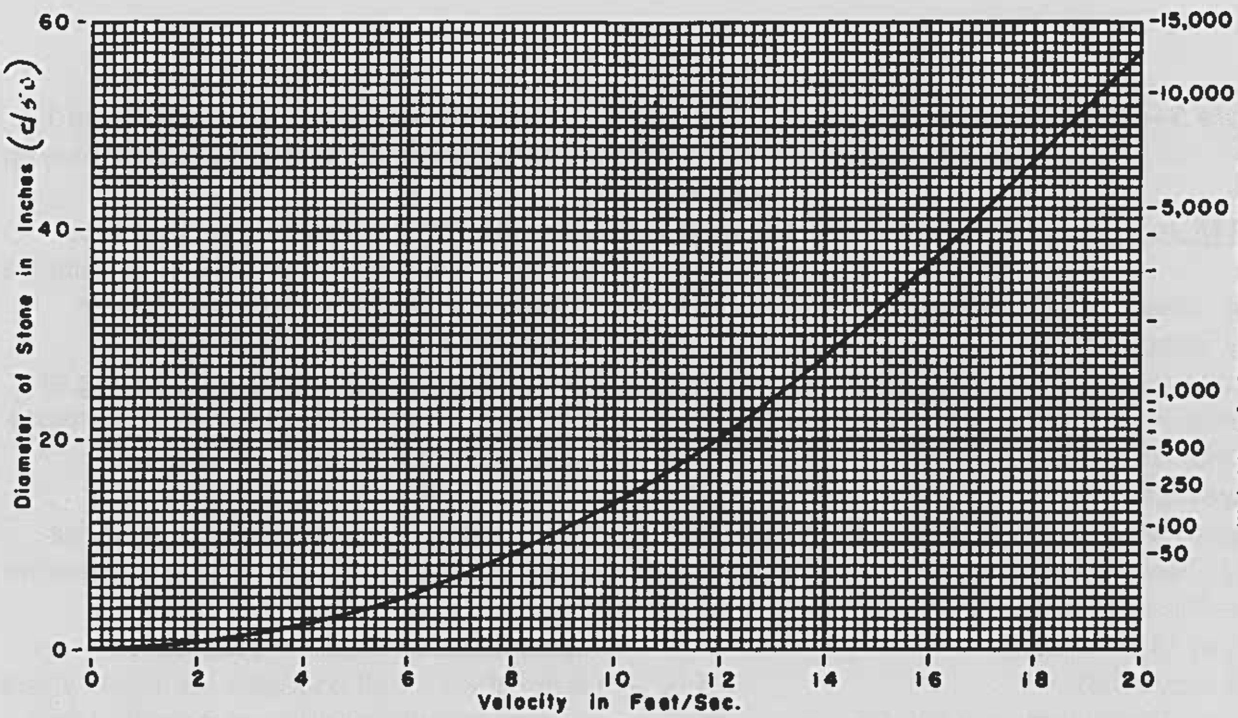


Figure 10 — Allowable Velocity for d_{50} Size

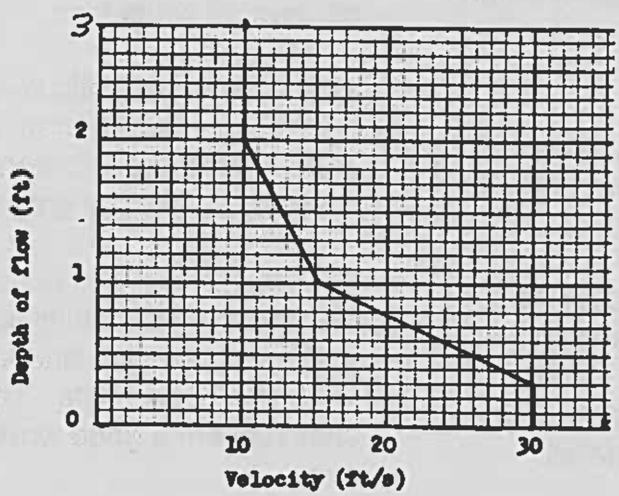


Figure 11 — Maximum Design Velocity vs Depth

Table 3 — Allowable Velocity for Soil.

Soil Material	Velocity ft/sec
Fine Clean Sands (SW, SP)	1.5
Silty Sand (SM)	2.0
Coarse Clean Sand (SW, SP)	2.5
Alluvial Silt, Noncolloidal (ML)	2.5
Alluvial Silt, Colloidal (MH)	3.0
Clayey Sand (SC)	3.0
Lean to Moderately Cohesive Clay (CL)	3.0
Silty Gravel (GM)	3.5
Fine Clean Gravel (GW, GP)	4.0
Clayey Gravel (GC)	4.5
Stiff Clay (CH)	4.5
Coarse Clean Gravel (GW, GP)	5.0
Cobbles and Boulders	6.0
Weathered Shale and Hardpan	6.0

Specifications

Detailed specifications shall be prepared for each installation. These specifications need to consider, as a minimum, the following items.

The foundation area shall be cleared of trees, stumps, roots, sod, loose rock, or other objectionable material.

The cross section shall be excavated to the neat lines and grades as shown on the plans. Over excavated areas shall be backfilled with moist soil compacted to the density of the surrounding material.

No abrupt deviations shall be permitted from design grade or horizontal alignment.

Concrete linings shall be placed to the thickness shown on the plans and finished in a workmanlike manner. Adequate precautions shall be taken to protect freshly placed concrete from freezing or extremely hot temperatures, and to insure proper curing.

Filter, bedding, and rock riprap shall be placed to line and grade and in the manner specified.
A protective cover of vegetation shall be established on all exposed surfaces where soil and climatic conditions permit. Lime and fertilizer shall be spread at the specified rate and shall be disked into the soil to a depth of 4 inches to prepare a seedbed. Seed and mulch shall be applied at the specified rate. In some cases, temporary vegetation may be used for protection until conditions are suitable for establishment of permanent vegetation.

Where soil or climatic conditions do not permit the establishment of vegetation, and protection is needed, nonvegetative means such as mulches or gravel may be used.

Construction operations shall be done in a manner that will minimize sediment, air, and water pollution and keep such pollution within legal limits. The completed job shall present a good workmanlike appearance.

Grassed Waterway

Definition: A natural or constructed channel that is shaped or graded to required dimensions and established in suitable vegetation for the stable conveyance of runoff.

Purpose: To convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding and to improve water quality.

Conditions Where Practice Applies: All sites where added capacity, vegetative protection, or both are required to control erosion resulting from concentrated runoff and where such control can be achieved by using this practice alone or combined with other water control practices.

Planning Considerations

Water Quantity: Effects upon components of the water budget, especially effects on volumes and rates of runoff should be considered.

Water Quality:

1. Filtering effects of vegetation on the movement of sediment, and dissolved and sediment attached substances will be evaluated. Suspended pollutants may move more quickly to a receiving water body.

2. Effects on the visual quality of the water resources will be evaluated. Concentrated erosion may be controlled or eliminated by the practice installation.

3. Short-term and construction-related effects on the quality of water resources will be considered.

Design Criteria

Capacity: The minimum capacity for grassed waterways shall be that required to confine the peak runoff expected from the storm of 10-year frequency (24-hour duration), except that on slopes of less than 1 percent out-of-bank flow may be permitted where such flow will not cause erosion or flood damage.

In cases where the waterway is to convey flows from a structure that is designed for a greater capacity than the 10-year frequency, the waterway will be designed to handle the same peak runoff as the structure without causing damage by erosion or flooding.

Velocity: Design velocities shall not exceed those contained in Table 4.

Width: The channel will be parabolic or trapezoidal. The bottom width of trapezoidal channels shall not exceed 50 feet. The top width of parabolic section shall not exceed 60 feet. Side slopes shall not be steeper than 4:1.

Depth: Minimum depth of a waterway receiving water from terraces, diversions, or other tributary channels shall be that depth required to keep the design water surface elevation in the waterway at or below the design water surface elevation in the terrace, diversion, or other tributary channel at their junction when both are flowing at design depth.

Drainage: Subsurface drains, underground outlets, stone center waterways, or other suitable measures shall be provided in the design for sites having prolonged flows, a high water table, or seepage problems. Water-tolerant vegetation such as reed canarygrass may be an alternative on some wet sites.

Outlets: All grassed waterways shall have a stable outlet with adequate capacity to prevent ponding or flooding damages. The outlet can be another vegetated waterway, an open channel, a grade stabilization structure, or other suitable outlet.

Protection: Grassed waterways, including some natural draws, may need flow protection until the establishment of vegetation.

Establishment of Vegetation: Grassed waterways will be vegetated according to the attached specification guide.

Design Aids

Appendix B may be used for estimating the runoff expected from a drainage area. Other guides which may be used include Chapter 2 of the Soil Conservation Service Engineering Field Handbook and SCS Technical Release 55.

The design for capacity and stability may be calculated by Manning's equation by taking into consideration the degrees of retardance of various vegetal covers. Designs will normally be based on retardance "D" for stability and permissible velocity and retardance "C" for capacity (top width and depth). Design procedures are outlined in detail in Chapter 7, Engineering Field Handbook.

Table 4 — Permissible velocities for grassed waterways

			Permissible Velocity		
Soil Texture	Bare Channel	Retardance[1]	Channel Poor	Vegetation Fair	Condition Good
	ft/s			ft/s	
Sand, silt,	1.5	B	2.0	3.0	4.0
sandy loam, &		C	1.5	2.5	3.5
silty loam		D	1.5	2.0	3.0
		B	3.0	4.0	5.0
Silty clay loam	2.0	C	2.5	3.5	4.5
& sandy clay loam		D	2.0	3.0	4.0
		B	3.5	5.0	6.0
Clay	2.5	C	3.0	4.5	5.5
		D	2.5	4.0	5.0
Coarse gravel	5.0	B, C, or D	5.0	6.0	7.0
Cobbles & shale	6.0	B, C, or D	6.0	7.0	8.0

[1] See Table 2 - Diversions

Operation and Maintenance

An O&M plan shall be developed to maintain waterway capacity, vegetative cover, and the outlet. The following items should be considered when developing the O&M plan:

a. Avoid crossing with machinery when waterway is wet.

b. Mow to control weeds and encourage development of a dense sod.

c. Remove heavy growth that will smother grass-legume stand.

d. Eroded areas should be reseeded or sodded promptly.

e. Apply 400 to 500 lbs per acre of 10-20-20 fertilizer to newly seeded waterway during the second growing season. Apply fertilizer when needed thereafter to maintain a vigorous grass-legume cover.

f. Do not permit spraying with herbicides that kill grass.

Plans and Specifications

Plans and specifications for grassed waterways shall describe the requirements for applying the practice to achieve its intended purpose.

Specifications

Areas to be excavated and areas to be occupied by spoil shall be cleared of trees, brush, and other debris as required for construction and maintenance.
Waterways shall be constructed to the line, grade, and section shown on the drawings. The excavated surfaces shall be reasonably uniform and smoothed in such a manner that normal seeding equipment can proceed with the establishment of vegetative cover without difficulty.

Spoil shall be placed or graded in such a manner that surface water may enter the waterway freely without scour. Spoil shall be used to fill depressions and shall be blended in with the surrounding topography.

All combustible refuse shall be burned or buried. When buried, all roots, brush, stumps, stones, and similar material shall be placed a minimum of 18-inches below finished grade. Runoff from diversions or other watersheds shall not be turned into the waterway until satisfactory vegetative cover or protection is established.

Seeding and Mulching: The following seed mixtures are the recommended combinations for vegetation of grassed waterways in pounds per acre:

a.	Kentucky bluegrass	20
	Redtop	3
	White Clover or	2
	Bird's-foot Trefoil	10

b.	Ky 31 tall fescue	35
	Creeping red fescue	30
	Redtop	3
c.	Reed canarygrass	25
	Weeping love grass	1
d.	Reed canarygrass	20
	Bird's-foot trefoil	10
	Redtop	3
e.	Ky 31 tall fescue	40
	Bird's-foot trefoil	10
	Redtop	3
f.	Orchard grass	10
	Ladino clover	2
	Redtop	3
g.	Tall fescue	50

When using netting to anchor mulch, the strips should be placed parallel to the direction of flow of water. Waterways should be sloped so that netting will lay evenly over the surface. Fasten ends of netting with wire staples 1 foot apart; fasten edges of netting with wire staples 3 feet apart. On steep waterways, wooden stakes 10 to 12 inches long should be used to replace one-fourth to one-third of the wire staples.

General: Construction shall be carried out in such a manner that erosion and air and water pollution will be minimized and held within legal limits. This shall be done by:

1. Placing spoil to prevent sloughing or washing into the ditch or watercourse.

2. Keeping chemicals, fuel, lubricant, sewage, and waste materials out of the ditch and drainage ways.

3. Establishing vegetation on all disturbed areas as soon as possible after exposure or disturbance, especially on ditch side slopes.

Water and Sediment Control Basin

Definition: An earth embankment or a combination ridge and channel generally constructed across the slope and minor watercourses to form a sediment trap and a water detention basin.

Purpose: To reduce watercourse and gully erosion, trap sediment, reduce and manage onsite and downstream runoff, and improve downstream conditions.

Conditions Where Practice Applies: This practice applies where:

1. The topography is generally irregular.
2. Watercourse and gully erosion are a problem.
3. Sheet and rill erosion are controlled to the extent possible by other conservation practices.
4. Runoff and sediment damage land and improvements or impair water quality.
5. Soil and site conditions are suitable.
6. Adequate outlets are available or can be provided.
7. Failure of the embankment will not result in loss of life or damage to roads, utilities, buildings or other improvements.
8. The total storage capacity, measured to the maximum settled fill elevation, for all basins in a series or for an individual basin, are within the following limits:

Maximum Embankment Height[1]	Maximum Accumulated Storage (all basins)	Maximum Storage (each basin)
Equal to or less than 6 ft.	50 ac-ft.	3 ac-ft.
6 feet to 15 ft	15 ac-ft.	3 ac-ft.

[1] The greatest height for any individual basin in the series, measured from the low point in the natural ground along the centerline of the embankment to the settled embankment elevation.

Effects on Water Quantity and Quality

This practice may reduce the volume and rate of discharge by using either underground outlets or soil infiltration outlets. When underground outlets are used, infiltration through the catchment area will be increased and runoff decreased. Peak flows will be reduced by temporary storage.

When soil infiltration outlets are used, infiltration may absorb most of the runoff. Deep percolation and groundwater recharge may occur when conditions permit. Where snow is available, it is often trapped in the channels and catchments of the practice and it infiltrates into the soil.

The practice traps and removes sediment and sediment-attached substances from runoff. Trap efficiencies for sediment and total phosphorous, that are transported by runoff, may exceed 90 percent in silt loam soils. Dissolved substances, such as nitrates, may also be removed from discharge to downstream areas because of the increased infiltration. Where geologic conditions permit, the practice will lead to increased loadings of dissolved substances toward ground water. Water temperatures of surface runoff, released through underground outlets, may increase slightly because of the longer exposure to warming during its impoundment.

Design Criteria

General: Water and sediment control basins (WASCOBS) can be part of the treatment needed to protect downstream areas from erosion and sediment damage. WASCOBS may be used with terraces, diversions, waterways, and sediment basins to provide needed protection downstream.

Spacing: WASCOBS shall be spaced to provide the required sediment capacity. The grade of the watercourse between basins shall be considered, and the spacing shall be set to prevent watercourse or gully erosion. The drainage of each basin shall be limited so duration of flooding, infiltration, or seepage does not damage areas or create other problems.

The system of basins shall be parallel when possible and spaced to accommodate maintenance requirements. Consideration shall be given to embankment slope lengths, top width, and inlet location when determining spacing.

Alignment: The embankment orientation shall be approximately perpendicular to the land slope.

Cross section: Embankment slopes shall not be steeper than 2h:1v. The top width shall be at least as wide as shown in the following table:

Fill Height (ft)	Top width (ft)
0-5	3
5-10	6
10-15	8

The constructed height of the embankment shall be at least 5 percent greater than but not more than 10 percent greater than the designed height to allow for settlement. The maximum settled height shall be 15 ft. measured from the natural ground at the centerline of the embankment. Slopes may be vegetated or rock-faced.

Capacity: The basin shall be large enough to control the runoff from a 10-year, 24-hour frequency storm without overtopping. The capacity of basins designed to provide flood protection or to function with other structures may be larger and shall be adequate to control the runoff from a storm of a frequency consistent with the other structures. Discharge through pipe outlets may be considered in determining the required storage volume.

The basin also shall have the capacity to store the anticipated 10-year sediment accumulation, unless provisions are made for periodic sediment removal from the basin to maintain the design capacity. When provisions are made for periodic sediment removal, the sediment storage volume will be equal to the volume of sediment expected between clean-outs.

Sediment yield (or annual sediment storage required) shall be taken from figure 17 of the standard for sediment basins.

Overflow Protection: Additional protection of the embankment may be provided by installation of emergency spillways, by flattening the downstream slope of the embankment, or by raising the fill elevation within the maximum 15-foot height limitation.

Emergency spillways may be either excavated or pipe spillways. The design capacity and resulting size of spillways will be based on the desired level of protection. However, installation of an emergency spillway and any desired freeboard shall not result in an embankment with a settled fill height greater than 15 ft. measured from the natural ground at the centerline of the embankment.

Excavated spillways may be parabolic, V-shaped, or trapezoidal in cross section. They will have a 2% or steeper inlet section followed by a 10 ft. long (minimum) level section. Side slopes will be no steeper than 2h:1v. Exit channel slopes will be no steeper than 10% when maintained in vegetation. A method of sizing excavated spillways is contained in the standard for sediment basins.

Pipe emergency spillways may be constructed of corrugated metal, concrete, polyvinyl chloride, or plate steel. No matter what material is used, the pipe shall be adequate to withstand the design height of embankment above the pipe. PVC pipe shall be ultraviolet resistant.

The emergency spillway must not contribute runoff to a lower basin in series that does not have an emergency spillway.

Outlets: Water and sediment control basins shall have underground outlets or soil infiltration outlets.

Outlets will be designed to drain the design runoff storage volume within 48 hours.

Inlets will be standpipes which will allow for accumulation of sediment without affecting the function of the inlet. Provisions should be made for raising inlets should the need for increased storage develop at a later date.

Vegetation and Protection: Slopes and disturbed areas shall be established to suitable erosion-resistant vegetation. If soil or climatic conditions preclude the use of vegetative cover and protection is needed, an organic or gravel mulch may be used. Seedbed preparation, fertilizing, seeding, and mulching shall be in accordance with the appropriate sections of this handbook.

Sediment Removal and Maintenance of Capacity: The sediment and design capacity shall be maintained by cleaning the basin when it has reached 60 percent of it's capacity or by raising the embankment height, within the 15 ft. maximum height limitation. Excavated material spread on the land shall be placed to not cause sedimentation problems in other areas.

Operation and Maintenance

An Operation and Maintenance Plan shall be developed for water and sediment control basins. The plan shall outline the minimum maintenance necessary to insure the basins function as designed. The plan shall address:

1. Frequent inspections and inspections after each major storm event.

2. Maintenance requirements and repair of damage to embankments, spillways, outlets and vegetation or fencing (if used) before major damage occurs.

3. Frequency or elevation when sediment removal is required.

4. Disposal methods for sediment removal.

5. Maintenance of vegetation (if used) by liming, fertilizing and mowing to prevent the growth of trees or other woody cover.

6. When infiltration outlets are used, occasional disking or plowing of the pool area may be required to maintain infiltration.

Plans and Specifications

Plans and specifications for installing water and sediment control basins shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

Drawings will be prepared to show the layout of the system in plan view and details of embankments, spillways, outlets, and fencing as appropriate. Drawings will indicate seeding materials rates and pipe material specifications when this information is not included in other specifications and when needed. Borrow areas and excess soil disposal areas will be indicated as needed.

Specifications for fencing, seeding, and underground outlets should be included as appropriate.

Specifications

The foundation area and borrow areas shall be cleared of trees, logs, stumps, roots, brush, boulders, sod, and rubbish. Topsoil having a high organic matter content shall be removed. Materials removed in the clearing operation will be burned, buried or otherwise disposed of as indicated on the drawings.

Topsoil will be stockpiled and spread on the completed embankment and borrow areas or spread to blend with the surrounding ground. Topsoil may also be used in the downstream face of the embankment and to flatten the downstream slope.

The foundation area will be thoroughly scarified before placement of fill material. The surface will have moisture added or be compacted if necessary so that the first layer of fill material can be compacted and bonded to the foundation.

The embankment, spillways and outlets will be constructed to the line, grade, and dimensions shown on the drawings or staked in the field.

Fill will be placed in layers not exceeding 8-inches in thickness and compacted by traversing the surface area of each layer with at least 4 passes of the construction equipment. The moisture of the fill material shall be sufficient to permit molding a firm ball when firmly squeezed in one's fist. The soil will not be so wet that water runs out when squeezed nor so dry that the ball easily crumbles when slightly deformed. Water may need to be added if too dry.

Upon completion of excavation and fill operations, all disturbed areas will be graded smooth and blend with the surrounding ground.

When pipes, vegetation, and/or fencing are required, they shall meet the requirements specified in the drawings or in other specifications for the types of materials and installation methods indicated.

Construction operations shall be carried out in such a manner and sequence that erosion and air and water pollution will be minimized and held within legal limits.

Sediment Basin

Definition: A basin constructed to collect and store debris or sediment.

Purpose: To preserve the capacity of reservoirs, ditches, canals, diversions, waterways, and streams; to prevent undesirable deposition on bottom lands and developed areas; to trap sediment originating from construction sites; and to reduce or abate pollution by providing basins for deposition and storage of silt, sand, gravel, stone, and other detritus.

Condition Where Practice Applies: This practice applies where physical conditions or land ownership preclude treatment of a sediment source by the installation of erosion-control measures to keep soil and other material in place or where a sediment basin offers the most practical solution to the problem. It may be used as a permanent or temporary measure during grading and development of areas.

This standard also establishes minimum acceptable quality for design and construction of a sediment basin and dam located in a predominantly urban setting when:

1. Failure of the structure would not result in the loss of human life; damage to homes, commercial buildings, highways or railroads; interruption of public utilities; or damage to existing water impoundments, and

2. The contributing drainage area does not exceed 200 acres, and

3. The vertical distance between the lowest point along the downstream toe of the dam and the lowest point along the top of the dam does not exceed 25 feet, and

4. The sediment dam conforms to all local and state laws pertaining to the storage of water.

Structures that do not conform to the above requirements shall be designed by a registered professional engineer.

Planning Considerations

Water Quantity: The following effects on water quantity should be considered:

1. Effects on the water budget, especially volumes and rates of runoff, infiltration, evaporation, deep percolation, and ground water recharge.

2. Effects on the water table and flow downstream and the results of changes of vegetative growth.

Water Quality:
The following effects on water quality should be considered:

1. Effects on erosion, movement of sediment, pathogens, and soluble and sediment attached substances.

2. Effects on the visual quality of onsite and downstream water resources.

3. Effects of construction and early establishment of protective vegetation on the surface and ground water.

4. Effects on wetlands and water-related wildlife habitats.

Design Criteria

Embankments: The design of dams, spillways, and drainage facilities shall be in accordance with this standard when the product of the height of dam and storage, to the emergency spillway elevation, does not exceed 3,000. When this limitation is exceeded, design shall be in accordance with SCS Technical Release 60.

Temporary basins having drainage areas of 5 acres or less and a total embankment height of 5 ft. or less may be designed with less conservative criteria if conditions warrant. The embankment shall have a minimum top width of 4 ft. and side slopes of 2:1 or flatter. An outlet shall be provided of earth, pipe, stone, or other devices adequate to keep the sediment in the trap and to handle the 10-year frequency discharge without failure or significant erosion.

Sediment Storage: The capacity of the sediment basin shall equal the volume of sediment expected to be trapped at the site during the planned useful life of the basin or the improvements it is designed to protect. If it is determined that periodic removal of sediment will be practicable, the capacity may be proportionately reduced.

Figure 17 may be used to size sediment basins. The annual yield per acre is determined from the nomograph and the total capacity needed is found by multiplying the annual yield by the area to be disturbed by the number of years the area will be disturbed.

Figure 16 may be used to size the sediment basin and determine the pertinent elevations and dimensions.

Detention Storage: In addition to the required sediment storage, the basin shall store the runoff from a 2-yr.—24-hr. storm to the top of the riser or principal outlet. The water stored from this storm will be released by a lower stage, nonclogging, dewatering device. The complete release of the stored water shall be accomplished no sooner than 24 hours after the storm and no later than 8 days after the storm. The elevation of the low stage shall not be lower than the maximum elevation of the design sediment storage volume.

The trap efficiency of the basin should be at least 90 percent effective in removing the sediment carried in the runoff from the site. Considerations in improving the efficiency of the basin are to control erosion in the disturbed area, reduce the velocity entering the basin, and use chemicals to induce flocculation of the sediment.

Watershed Area: The contributing watershed area above the site should have a plan to provide the maximum protection against erosion of the disturbed areas. In as much as possible, the runoff from above the site shall be diverted around the site to prevent it adding to the erosive force of the runoff from the disturbed area itself.

Structures in Series: When structures are built in series, the principal spillway and emergency spillway sizes for the lower structure shall be based on the total drainage area above the lower structure. Construction of series sites must proceed in an upstream direction. All upstream sites must be constructed after the lower site is constructed. This limits the initial sediment escaping from the site to only one structure installation.

When an existing upstream structure is not considered adequate or safe according to the requirements herein, a lower structure in series must be designed to consider possible failure of the upstream structure. This means the sediment capacity and detention capacity must be designed as if the upstream structure did not exist.

Principal Spillway: A drop inlet type principal spillway is required for all structures, with the following exception. Where the drainage area is less than six (6) acres total and there is no spring flow that enters the basin at any time during the year, the requirement for a pipe principal spillway is waived.

The hydrologic and hydraulic design of the principal spillway shall be in accordance with the following conditions:

1. The distance between the crest of the principal spillway and the crest of the emergency spillway shall not be less than one (1) foot.

2. The minimum diameter of conduit shall be 12 inches.

3. The inlet to the principal spillway shall be located to prevent short-circuiting. This can be achieved by having the length to width ratio of the basin 3:1 or greater, or installing baffles.

4. The minimum size for the principal spillway barrel and drop inlet shall be obtained from Table 5, Principal Spillway Criteria, and Table 6, Minimum Required Principal Spillway Size.

Layout: The principal spillway shall be a straight alignment. The minimum slope of the conduit shall be one (1) percent.

Outlet: The outlet end of the conduit must extend to an elevation at least one (1) foot above the stable channel bottom and a minimum of 6 feet beyond the toe of dam. Pipe supports shall be installed for outlets where the cantilevered portion is more than 35 percent of the length of the last section of pipe measured along the bottom of the pipe. For pipe diameters greater than 15 inches, an outlet support is required when the cantilevered portion of the last section of pipe is more than 20 percent of the total length of the section, measured along the bottom of the pipe.

Energy dissipating outlet structures are required below the pipe outlet when the bottom of the channel is not bedrock, or the pipe diameter exceeds 18-inches. The outlet structure may be constructed of rock riprap or concrete. Rock riprap shall be reasonably well-graded between the limits of 6- and 24-inches. Designs for concrete outlet structures and riprap for pipe outlets larger than 36 inches diameter shall be prepared by an engineer experienced in hydraulic design.

Pipe Conduits: Pipe conduits must withstand the internal hydrostatic pressure without leakage while subject to the full

Table 5 — Principal Spillway Criteria
Product of Height X Storage is 3,000 or less

Drainage Area Acres	Effective Height1 Feet	Pipe Diameter (in.) or minimum Design Storm Frequency[2]
0 to 50	35 or less	12 inches
50 to 75	20 or less	15 inches
	21 to 35	5 yr - 24 hr
75 to 100	20 or less	18-inches
	21 to 35	5 yr - 24 hr
100 to 150	20 or less	24 inches
	21 to 35	5 yr - 24 hr
150 to 200	20 or less	30 inches
	21 to 35	5 yr - 24 hr
200 or more	20 or less	5 yr - 24 hr
	21 to 35	10 yr - 24 hr

[1] Low point along downstream toe to crest of emergency spillway.
[2] To the top of riser or principal spillway outlet.

external load and settlement. Material guidance and minimum strength requirements are governed by the appropriate ASTM specification. Considerations for each type of pipe are detailed as follows.

1. Asbestos cement and concrete - These rigid conduits must be laid on a concrete bedding. A safety factor of at least 1.5 shall be applied to the computed three-edge bearing strength requirement to determine allowable height of fill over the conduit.

Bedding — Concrete bedding shall be placed beneath the pipe at a minimum thickness of 4 inches and extend up the sides of the pipe for at least 10 percent of the overall height of the conduit. The bedding shall have a base width of at least the outside diameter of the pipe.

Joints — Conduit joints are to be designed and constructed to remain watertight. A rubber gasket is to be set in a positive seat which will prevent displacement.

2. Corrugated metal pipe

   Iron or steel (zinc coated) — Pipe shall be close-riveted and asphalt-coated or helical-corrugated with welded seam and can be used only where the pH of the normal flow is 5.0 or greater. When the pH of the flow is expected to be less than 5.0, the pipe shall be close-riveted, asbestos-bonded, bituminous-coated, and have a paved invert. The minimum wall thickness of the pipe shall be 16 gage for conduits 18-inches or less in diameter. For larger sizes, the minimum wall thickness shall be 14 gage.

   Bituminous coatings damaged in transport or placement shall be repaired by the application of 2 coats of hot asphaltic paint or cold-applied bituminous mastic.

   Aluminum — Corrugated aluminum shall only be used in soils having a pH greater than 5.0 and less than 9.0. The minimum wall thickness of the pipe shall be 14 gage.

   Joints — All corrugated metal pipe shall be connected by a water-tight flange-type connection or by a water-tight connecting band specifically manufactured for use as a connecting band (with rods and lugs). The area between the pipe and the connecting band shall be treated with an asphalt cement during installation to insure a water-tight joint. Neoprene gaskets may be used in lieu of the asphalt cement if they have been specifically manufactured for that use.

3. Steel (smooth) - Steel pipe may be used where the pH of the normal stream flow during the life of the structure will be 5.0 or greater. Steel pipe shall be standard strength and shall be connected by a water-tight mechanical or welded joint.

4. Wrought-Iron or Cast Iron - Iron pipe may be used under all soil and water conditions. It must be of standard thickness or greater and be connected by a water-tight mechanical or welded joint.

5. Polyvinyl Chloride (PVC) Plastic Pipe - PVC1120 or PVC1220 (Schedule 40, 80, or SDR26) conforming to ASTM D-2241 or ASTM D-1785 may be used.

Drop Inlets: The drop inlet must be designed to facilitate the passage of the runoff in excess of the detention storage. The detention drawdown is accomplished by slotting the riser or by a siphon device. This will insure the desired sediment trapping.

Gravel is not recommended around the slotted risers. It will tend to seal with sediment. When non-slotted risers are used, the riser must be stable against floating. The safety factor against uplift must be at least 1.25.

Conduit-type drop inlet risers shall have a base, attached with a water-tight connection, that has sufficient weight to meet the uplift force criteria.

Anti-vortex Device: Drop inlet risers shall be equipped with an anti-vortex device when the flow through the conduit is considered in sizing an emergency spillway.

Trash Rack: A trash rack will be utilized where the drainage area is expected to contribute trash to the basin, or when the flow in the conduit is considered in sizing an emergency spillway. A trash rack is not an anti-vortex device and an anti-vortex device is not a trash rack.

Seepage Control: Where the embankment is greater than 10 feet high, and the conduit is larger than 10 inch diameter, positive antiseep measures are required along the pipe. Antiseep measures may be of two types: collar and flange, or sand diaphragm.

Collar and flange devices shall be installed with a water-tight connection to the pipe, and shall extend a minimum of two (2) feet in every direction from the pipe. The collar and flange shall be of material that is compatible with the pipe conduit. A minimum of one (1) collar and flange is required.

Sand diaphragms shall be constructed using ASTM C-33 fine concrete aggregate as a filter material. The sand diaphragm shall extend two (2) feet in every direction from the pipe and shall be a minimum of two (2) feet thick along the pipe. The outlet for the sand diaphragm shall extend along the pipe to the toe of the dam. It shall be of the same sand material and must have at least two (2) square feet of area normal to the flow. The conduit should be bedded in the outlet material with at least six (6) inches of material extending vertically below the conduit. The surface of the outlet must be protected against erosion by lining with riprap.

Drain: Provision shall be made to drain the sediment pool if the effective height of the embankment is 15 feet or more. The principal spillway may be utilized as the drain if the riser is gated to allow drawdown and the inlet can be protected against clogging. A separate drain pipe shall not be less than 1 and 1/4 inches diameter and shall be capable of draining the pool in ten (10) days or less.

Table 6 — Minimum Required Principal Spillway Size

Drain. area (acres)	Conduit Diameter (inches)	Drop Inlet Diameter (inches)	Square Drop Inlet Dimensions (feet)	Minimum Drop Inlet Height (feet)
0-50	12	18	2 X 2	2.0
50-75	15	24	2 X 2	2.5
75-100	18	30	2 X 2	3.0
100-150	24	36	2.5 X 2.5	4.0
150-200	30	42	3 X 3	5.0

Emergency Spillway: Emergency spillways are needed to convey large flows safely past the dam. They usually consist of open channels excavated in earth or rock. They can consist of structural measures such as a concrete channel.

Where the height of dam is 15 feet or less, the requirement for an emergency spillway is waived if the contributing drainage area is less than 20 acres and the principal spillway has a non-clogging drop inlet with a conduit diameter of at least 24 inches.

For all other sites, The 10-yr.—24-hr. storm runoff shall be stored with no flow out the emergency spillway.

Where the product of drainage area and effective height of dam (DA X H) is between 400 and 4,000, the emergency spillway design storm shall be a 25-yr.—24-hr. frequency. The minimum freeboard required above the emergency spillway outflow is one (1) foot.

Where the product of drainage area and effective height of dam exceeds 4,000, the emergency spillway design storm shall be the 50-yr.—24-hr. frequency. The minimum freeboard above the emergency spillway outflow is two (2) feet.

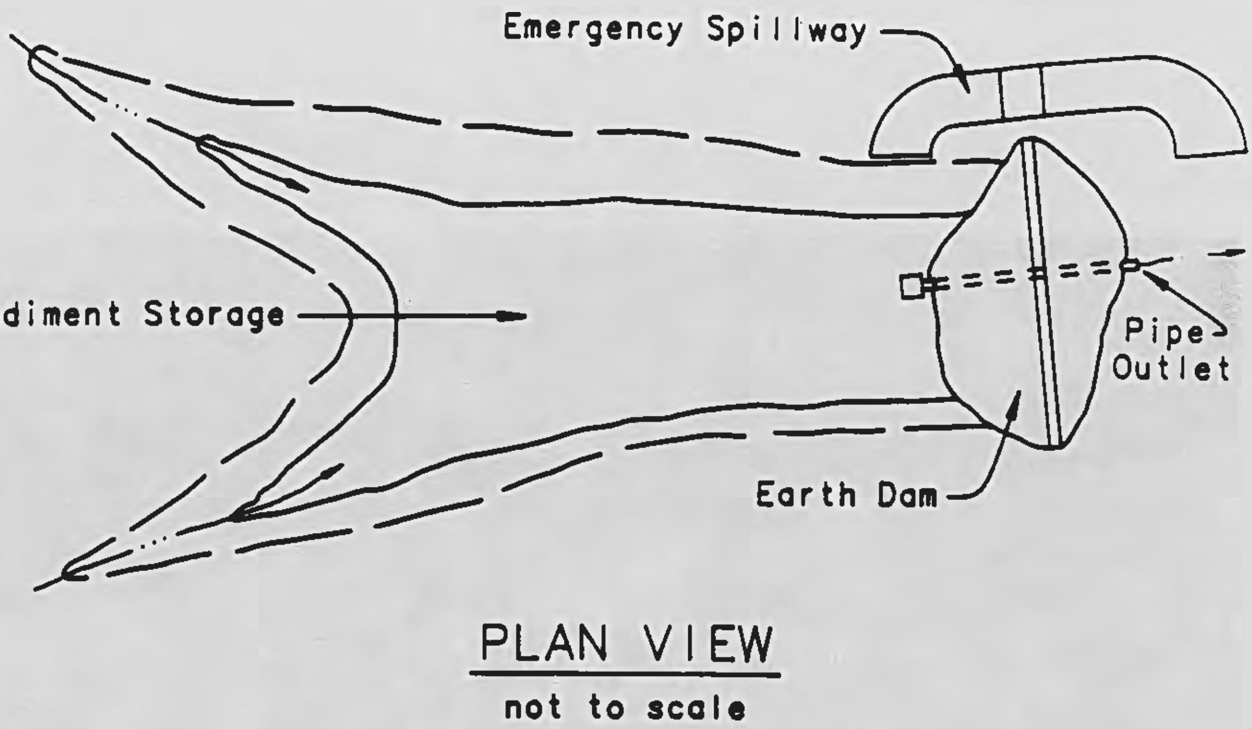
Layout: Minimum bottom width shall be 8 feet. The spillway channel shall be trapezoidal when constructed in earth materials. Side slopes shall be 2h:1v, or flatter. It may have vertical side walls where constructed in rock or of concrete.

The control section shall be located at or downstream of the centerline of dam. The inlet channel shall be level for a distance of 25 feet upstream of the control section. The level section and the exit channel shall be of the same width. The inlet channel may flare to a wider width upstream of the level section or have a curved layout upstream of the level section. The inlet channel should have a minimum slope of two (2) percent in the upstream direction.

The outlet channel shall not release flow that impinges on the toe of the dam. It shall extend to a stable grade in the valley. Curvature may be used in the outlet channel downstream of the toe of the embankment. The outlet channel shall be designed to be stable under design flow conditions. Any procedure that is generally accepted by the engineering profession may be used to design the emergency spillway. If no other procedure is desired, the spillway may be sized using either Table 8 or 9. Outlet channel allowable velocities are listed in Table 7.

Table 7
Permissible Velocities
Feet-per-second

Vegetated, soil is	
Erosion-resistant	5.5
Erodible	3.5
Riprap lined	12.0
Rock	14.0



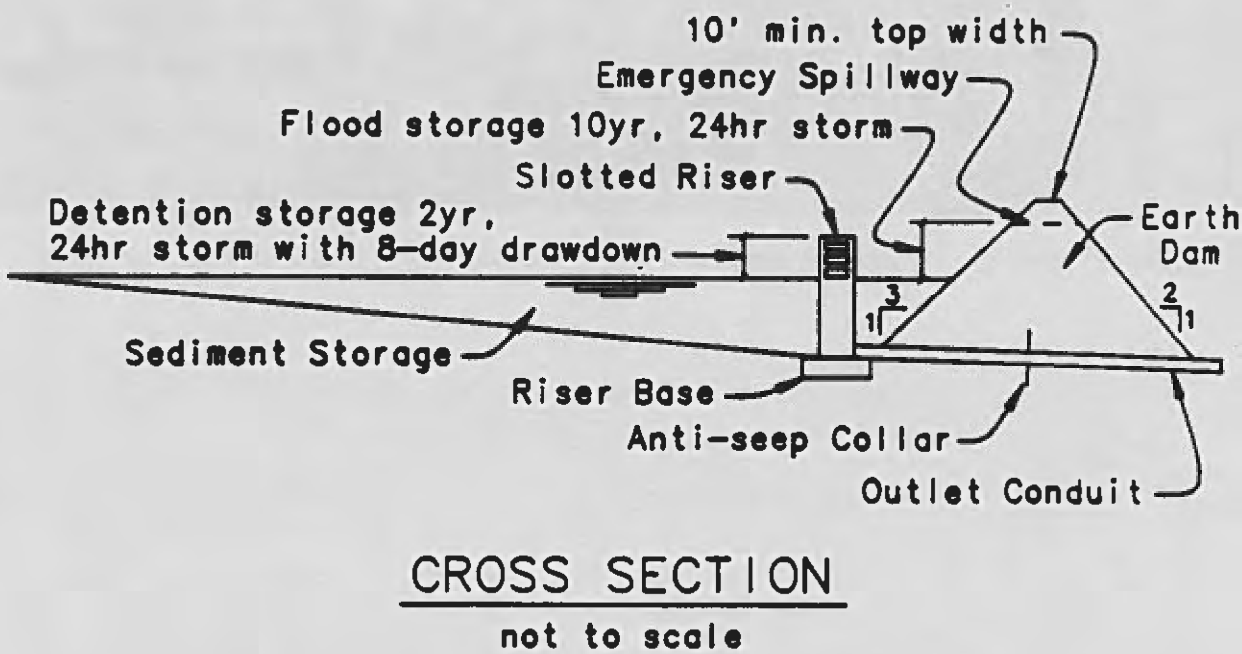
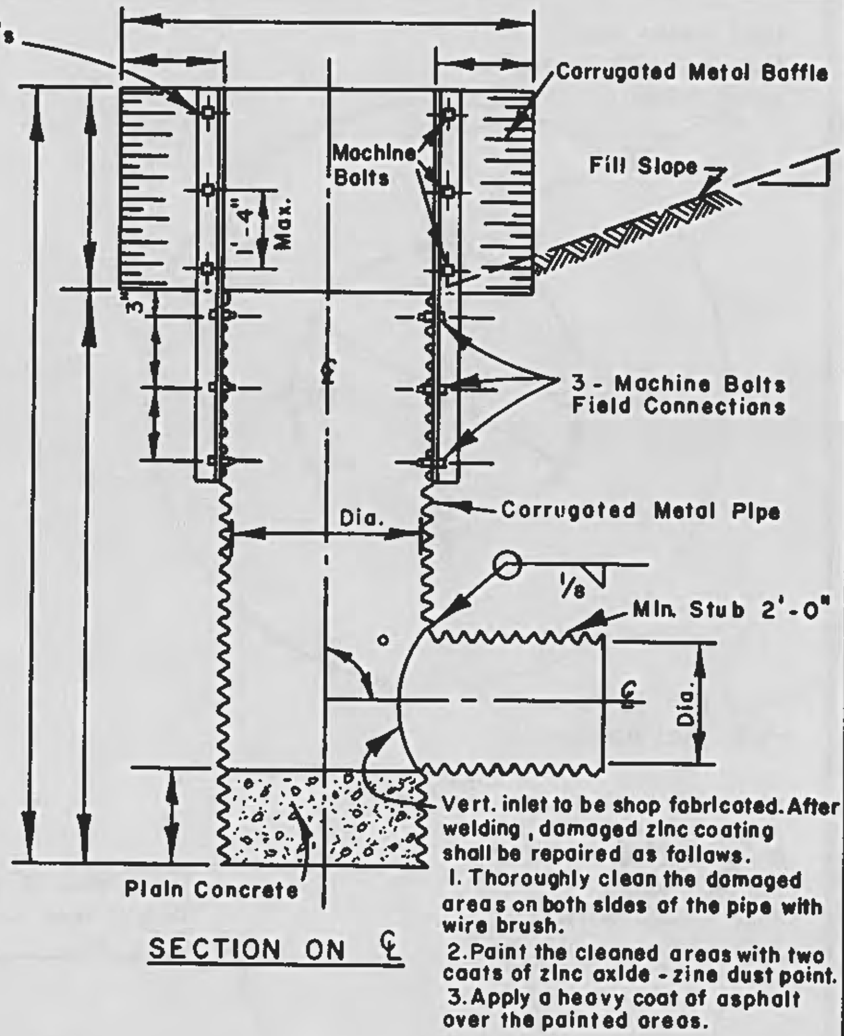


Figure 12 — Plan View and Cross Section of Sediment Basin

A Sediment basin catches and stores sediment from construction areas and keeps it out of streams.

CORRUGATED METAL (STEEL) PIPE INLET WITH SHORT SPLITTER BAFFLE



BILL OF MATERIALS			
ITEM	SIZE	LENGTH	QUAN.
Angles	2 1/2" x 2 1/2" x 1/4"		2
Steel Cadmium Plated Mach. Bolts W/Nuts & Lockwashers	1 1/2" Dia.	1 1/4"	12
C.M. Baffle	ga.	x	1
C.M. Pipe (Riser)	"Dia. ga.		1
C.M. Pipe (Stub)	"Dia. ga.	24"	1
Volume of Concrete in Cu. Yds.			

Note: All holes for bolts shall be 9/16" diameter.

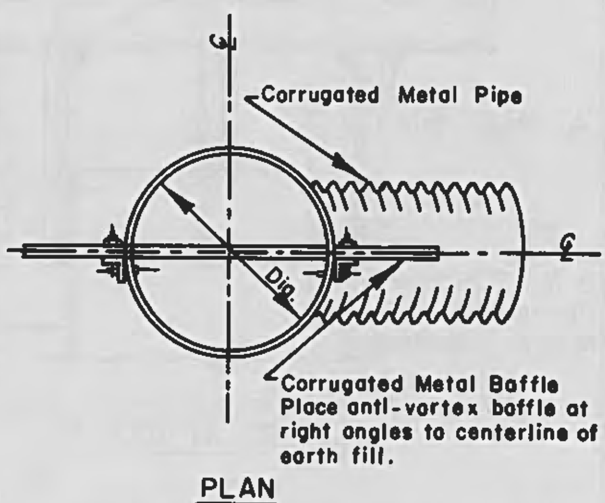
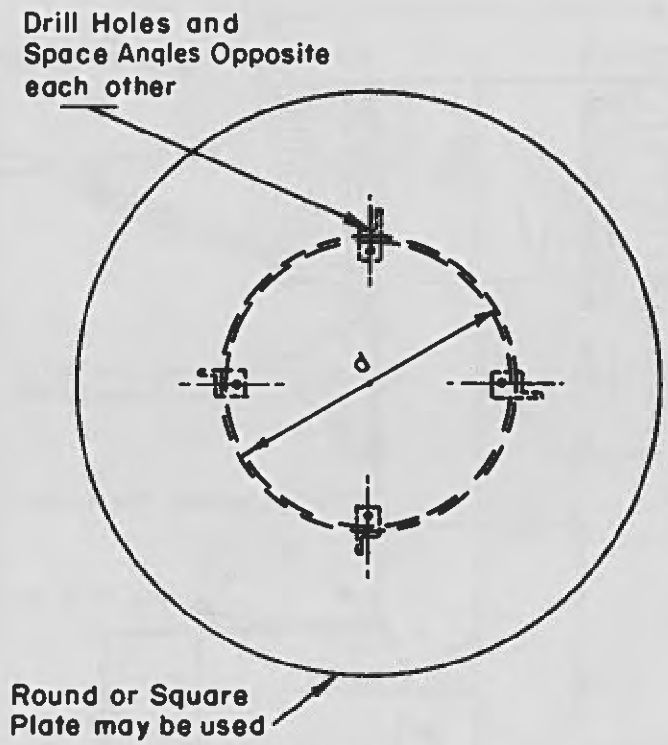
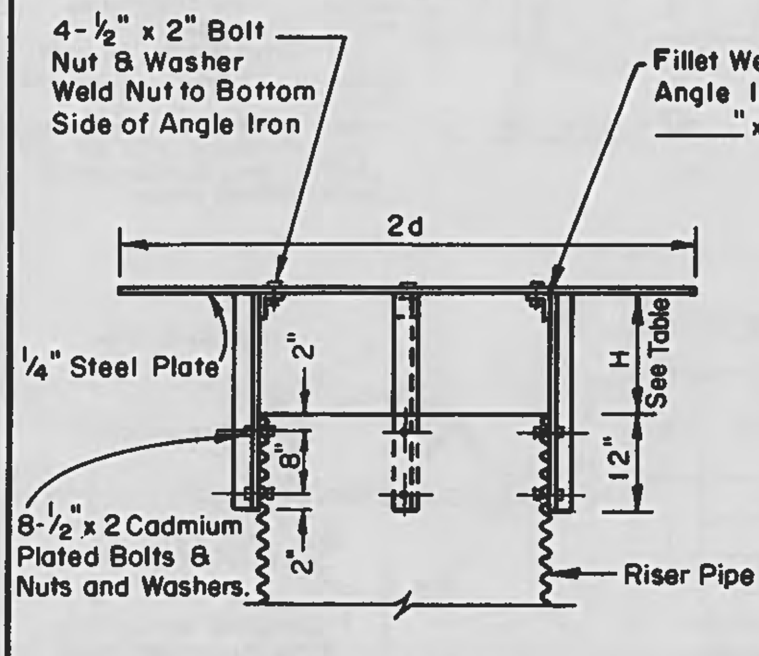


Figure 13

ANTI - VORTEX - TRASH AND SAFETY GUARD



PLAN



SECTION AT CENTER

Inlet d Dia. Inches	Barrel Dia. Inches	H Inches
12	6	6
12	8	6
15	10	6
15	12	7
18	12	6
24	15	7½
24	18	10
* 30	18	8½
* 30	24	13½
* 36	24	12

* Use Angle Iron Stiffeners on Plate as Specified.

Figure 14

Earth Embankments: The embankment for permanent sediment basins shall have a minimum top width of ten (10) feet. The side slopes of the embankment shall be no steeper than 3h:1v upstream and 2h:1v downstream.

Embankments for basins without emergency spillways shall have a downstream side slope of 5h:1v or flatter and the downstream slope shall be protected by a riprap lining designed to be stable, but with a minimum D_{50} of 9-inches and a maximum size of 18-inches.

The design height of embankment shall be constructed ten (10) percent higher to allow for settlement.

A cutoff trench shall be used to protect the embankment against foundation piping. It shall extend to an impervious layer below the surface soils, and be a minimum of three feet deep. The trench shall extend up the abutments to at least the crest elevation of the principal spillway. The cutoff shall be trapezoidal in cross-section, with a minimum bottom width of 8 feet. Side slopes shall be no steeper than 1:1. The most impervious material available shall be used to backfill the cutoff trench.

Other Types of Dams: Sediment basin structures may also be constructed of rock-filled pressure treated timber cribbing, rock-filled precast reinforced concrete cribbing, or rock-filled gabions. These types of retaining structures do not require the use of a pipe spillway, but do require provision for the emergency spillway frequency storm. Designs for these types of structures must be prepared by a registered professional engineer for the specific site and conditions.

Safety: Guardrails, fencing and signs should be used to control access to sediment basins.

Vegetation: Vegetation of all disturbed areas shall be accomplished in accordance with the appropriate section of this handbook.

Sediment Removal and Removal of the Basin: Sediment removed during intermediate clean out of the basin will be spread uniformly above the pool area or in other areas where it will not enter the stream. The area will be immediately fertilized, limed, seeded and mulched.

The same procedure will be applicable when the basin has reached its design life and removal is required.

Operation and Maintenance

An operation and maintenance plan shall be developed for the installed basin. The plan shall outline the minimum maintenance necessary to ensure the basin functions for its design life. The plan should consider, as a minimum, the following items.

1. Inspect after every rainfall event. Clean out or repair as necessary.

2. Keep stabilization features in proper condition. This would include vegetation, riprap, pipes, and open spillways.

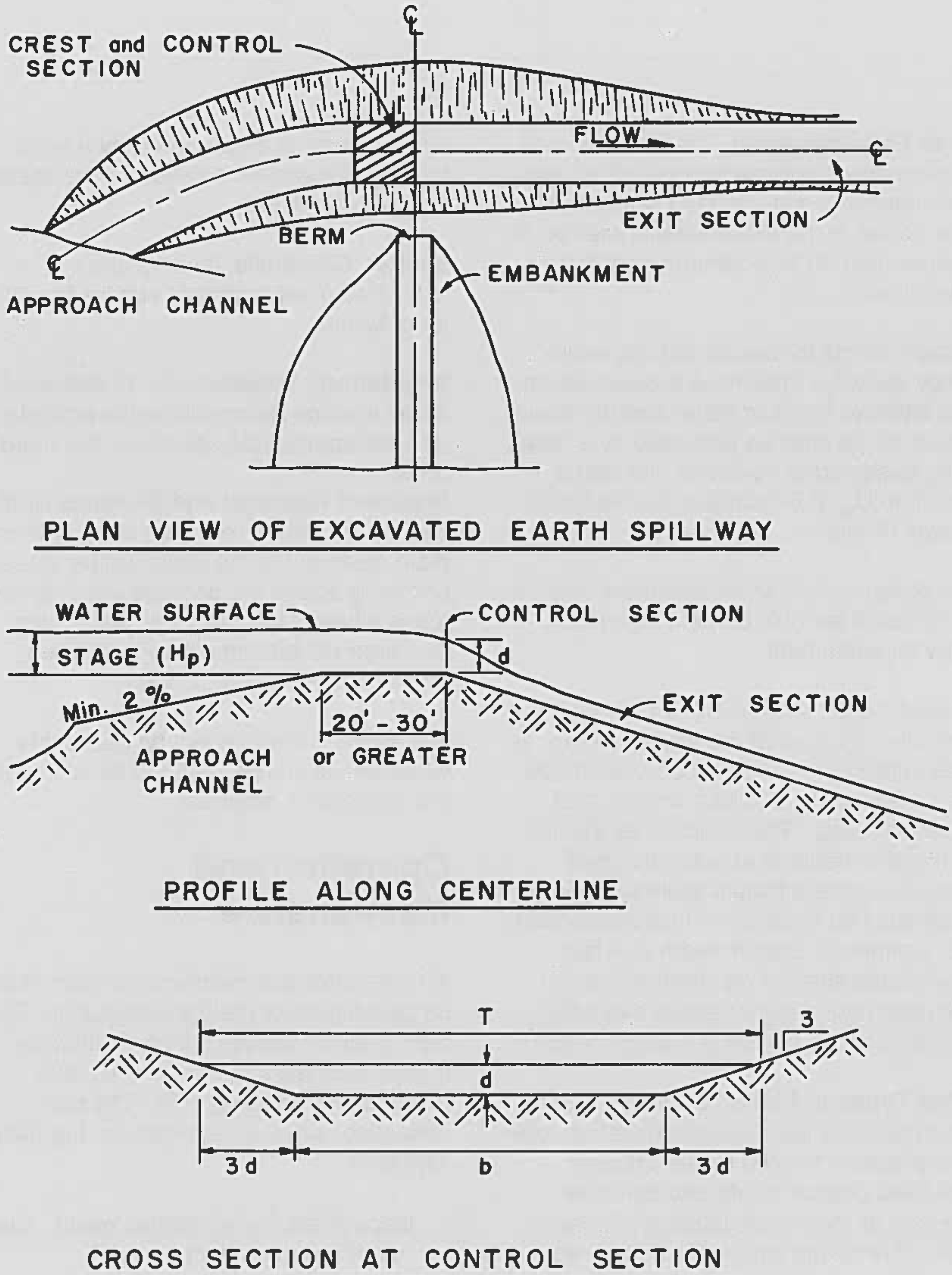

CREST and CONTROL SECTION
FLOW
EXIT SECTION
BERM
EMBANKMENT
APPROACH CHANNEL
PLAN VIEW OF EXCAVATED EARTH SPILLWAY
WATER SURFACE
CONTROL SECTION
STAGE (Hp)
d
Min. 2 %
20' - 30' or GREATER
APPROACH CHANNEL
EXIT SECTION
PROFILE ALONG CENTERLINE
T
3
1
d
3d
b
3d
CROSS SECTION AT CONTROL SECTION

Figure 15

Table 8 **— H_p and Slope Range for Discharge and Velocity**
Retardance C[1]
Crest Length 25'

Max. Velocity V	Discharge q	H_p	Exit Slope Range min.	Exit Slope Range max.
ft/s	cfs/ft	ft	pct	pct
2	0.5	0.7	1	6
2	1	0.9	1	3
3	1.25	0.9	1	6
4	1.5	1.0	1	12
4	2	1.1	1	7
5	3	1.3	1	6
6	4	1.5	1	12
8	5	1.7	1	12
9	6	1.8	1	12
9	7	2.0	1	10
10	7.5	2.1	1	12

Table 9 **— H_p and Slope Range for Discharge and Velocity**
Retardance D[2]
Crest Length 25'

Max. Velocity V	Discharge q	H_p	Exit Slope Range min.	Exit Slope Range max.
ft/s	cfs/ft	ft	pct	pct
2	0.5	0.6	1	6
3	1	0.8	1	6
3	1.25	0.8	1	4
4	1.25	0.8	1	10
4	2	1.0	1	4
5	1.5	0.9	1	12
5	2	1.0	1	9
5	3	1.2	1	4
6	2.5	1.1	1	11
6	3	1.2	1	7
7	3	1.2	1	12
7	4	1.4	1	7
8	4	1.4	1	12
8	5	1.6	1	8
10	6	1.8	1	12

[1] Vegetation 11 to 24 inch length.
[2] Vegetation 2 to 10 inch length.

Plans and Specifications

Plans and specifications for installation of sediment basins shall be in sufficient detail to insure the practice will function to achieve its intended purpose.

Removal and disposal of sediment and removal of the sediment basin will be addressed in the drawings or specifications.

Design Aids

Reference may be made to Appendix B for a procedure to determine runoff for a given watershed area. Other guides which may be used include Chapter 2 of the Soil Conservation Service Engineering Field Handbook and SCS Technical Release 55.

Figure 17 is a sediment volume curve to be used in computing the quantity of sediment storage needed for a sediment basin. Tables 8 and 9 provide a method for sizing the emergency spillway based on the design flow. Figure 16 is a structure design sheet which contains pertinent details leading to a structure size.

Additional design procedures may be found in SCS Engineering Field Handbook, Chapter 11; Ponds and Reservoirs.

Specifications

Construction operations will be carried out in such a manner that erosion and water and air pollution will be minimized. State and local laws concerning pollution abatement will be followed.

Site Preparation: The embankment site shall be cleared of all brush, trees, stumps, roots, and other undesirable material. Sod and topsoil shall be stripped from the embankment site and borrow area and stockpiled for use on the emergency spillway and embankment. Brush, trees, and other undesirable material shall be cleared from the sediment pool area.

Excavation and Backfill of Stream Channel: Existing stream channels crossing the foundation area shall be deepened and widened as necessary to remove all stones, gravel, sand, stumps, roots, and other objectionable material, and to accommodate compaction equipment. Such channels shall then be backfilled with suitable material as specified for earth embankment. The excavated channels shall be kept free of standing water during backfill operations.

Pipe Conduit: The pipe conduit shall be placed in a trench excavated in solid, undisturbed ground or formed by compacted earth. The conduit, except where placed on concrete bedding, shall be imbedded in a formed trench to a depth no less than one-tenth times the outside diameter of the pipe. Trench sides shall be sloped back no steeper than 1 to 1. Selected impervious backfill material shall be placed around the conduit in 4-inch layers and thoroughly compacted to at least the same density as the adjacent embankment.

All pipe joints and anti-seep collar connections to the conduit shall be watertight.

Emergency Spillway: The emergency spillway shall conform to the lines, grades, bottom width, and side slopes as shown on the plans.

Borrow Areas: All borrow excavation will have side slopes no steeper than 2h:1V and shall be graded and left in such a manner as to provide suitable drainage.

Selection and Placement of Embankment Materials: The most impervious material shall be used in the cutoff trench and center portion of the dam. When sandy gravelly material is encountered, it should be placed in the outer shell, preferably in the downstream portion of the dam. The distribution and gradation of materials throughout the fill shall be such that there will be no lenses, pockets, streaks, or layers of material differing substantially in texture or gradation from the surrounding material. Where it is necessary to use materials of varying texture and gradation, the more impervious material shall be placed in the upstream and center portions of the dam. Very dry or wet materials shall not be used. The fill material shall be free of all sod, roots, and stones, over 6 inches in diameter, and other objectionable material. The moisture content of the material should be such that when kneaded in the hand it will just form a ball that will not readily separate.

The embankment material shall be placed in uniform 6- to 8-inch layers over the entire embankment area. Compaction shall be obtained by completely traversing each layer with a minimum of four passes of the construction equipment.

Figure 16
Sediment Basin Proportioning
Computation Sheet

Project ______________________________

Location ______________________________

Computed by ____________ Date__________ Checked by____________ Date__________

Design Factors

Drainage Area ________Ac. Max. Effective Height ______Ft. Max. Storage ________Ac. Ft.
(Ht. between ESW crest and low point)

Sediment Storage

Ave. Slope ______% Ave. Slope Length ________Ft. Area Disturbed ________Ac.

Required Sediment Storage = **Sa** x **A** x **Yr**

Sa = Annual Sediment Storage per Acre = __________Ac. Ft. (Figure 17)

A = Area Disturbed = ____________Ac.

Yr = Design Life = ____________Yrs.

Sediment Storage V = __________ x __________ x __________ = __________ Ac. Ft.[1]

Sediment Pool Elevation: ______________

Pipe Spillway

Design Storm (If required) __________ (Table 5) Peak Flow (If required) (qp)____________ cfs (Appendix B)

Diameter ____________ (Table 5) In. Length ____________ Ft. Material ____________

Drop Inlet Size ____________ (Dia x Ht or L x W x Ht) Material ______________ Stage to ESW Crest ________Ft.

Pipe Peak Discharge (If required) _____ cfs Additional Seepage Protection __________
("None," "Anti-Seep Collars," or "Drainage Diaphragm")

Pipe Outlet Protection ________________ ("None," "Splash Pad," "Plunge Pool," or "Riprap Line")
PSW Inlet Protection ________________ ("None," "Anti-vortex Plate," and/or "Trash Rack")

Vegetated Earth Spillway

Soil Type ___________ (USCS) Vegetation ___________ (Species) Resistance to Erosion ____________ ("Resistant," or "Easily Eroded")

Allowable Velocity (Va) ________fps (Table 7) Design Storm __________ Peak Flow (q_p)__________cfs (Appendix B)

Bottom Width ______ Ft. Stage (Hp) ______ Ft. (Table 8 or 9) Side Slopes (Z) Inside ______ Outside _____

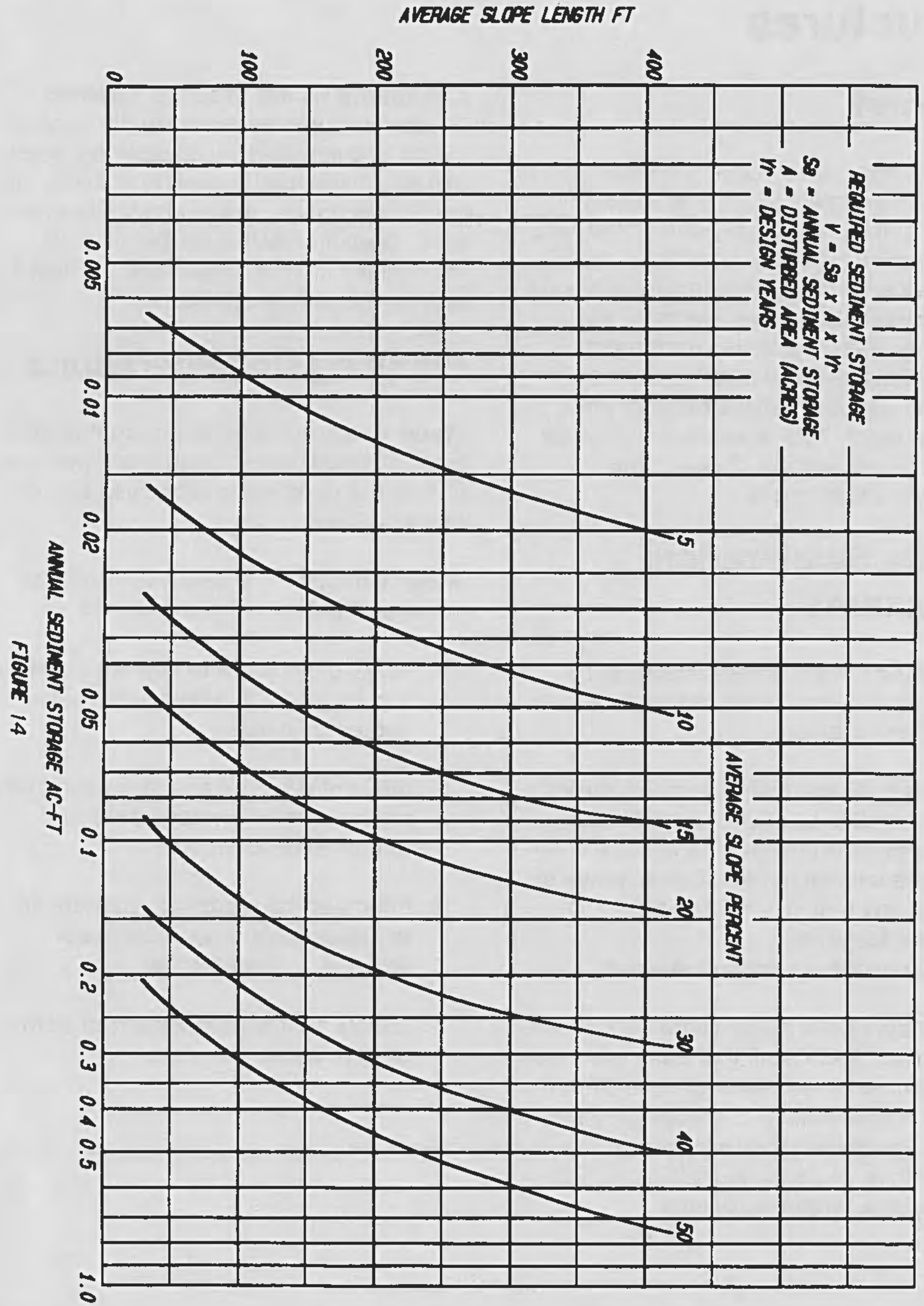
Exit Channel Slope — max. ________ % Min. ________ % (Table 8 or 9) Inlet Channel Slope __________% (Should be ≥ 2%)

Length of Level Section ________ Ft. Max. Design Velocity ________fps (Must be < allowable velocity) Freeboard ______Ft. (2 ft. min.)

Top of Dam Elevation: ______________________

[1]May be divided by anticipated cleanouts per year.

Figure 17


AVERAGE SLOPE LENGTH FT
0
100
200
300
400
REQUIRED SEDIMENT STORAGE
V = Sa x A x Yr
Sa = ANNUAL SEDIMENT STORAGE
A = DISTURBED AREA (ACRES)
Yr = DESIGN YEARS
AVERAGE SLOPE PERCENT
5
10
15
20
30
40
50
0.005
0.01
0.02
0.05
0.1
0.2
0.3
0.4
0.5
1.0
ANNUAL SEDIMENT STORAGE AC-FT
FIGURE 14

Grade Stabilization Structures

General

A grade stabilization structure lowers water from one elevation to another without erosion. It stabilizes the grade or controls head cutting in natural or artificial channels. Overfall structures may be designed using materials such as concrete, rock, masonry, steel, aluminum, or treated wood. Pipe drops of metal pipes with suitable inlet and outlet structures may also be used. Typical examples of grade control structures are shown in the sketches which follow.

Grade Stabilization Structures

Definition: A structure to stabilize the grade or to control head cutting in natural or artificial channels.

Purpose: Grade stabilization structures are installed to stabilize the grade and control erosion in natural or artificial channels, prevent the formation or advance of gullies, and reduce environmental and pollution hazards.
Conditions Where Practice Applies

These structures apply where the concentration and flow velocity of water are such that structures are required to stabilize the grade in channels or to control gully erosion. Special attention will be given to maintaining or improving habitat for fish and wildlife, where applicable.

Conditions Where Practice Applies: These structures apply where the concentration and flow velocity of water are such that structures are required to stabilize the grade in channels or to control gully erosion. Special attention will be given to maintaining or improving habitat for fish and wildlife, where applicable.

Planning Considerations

Water Quantity: Effects on volumes and rates of runoff, evaporation, deep percolation, and ground water recharges should be considered.

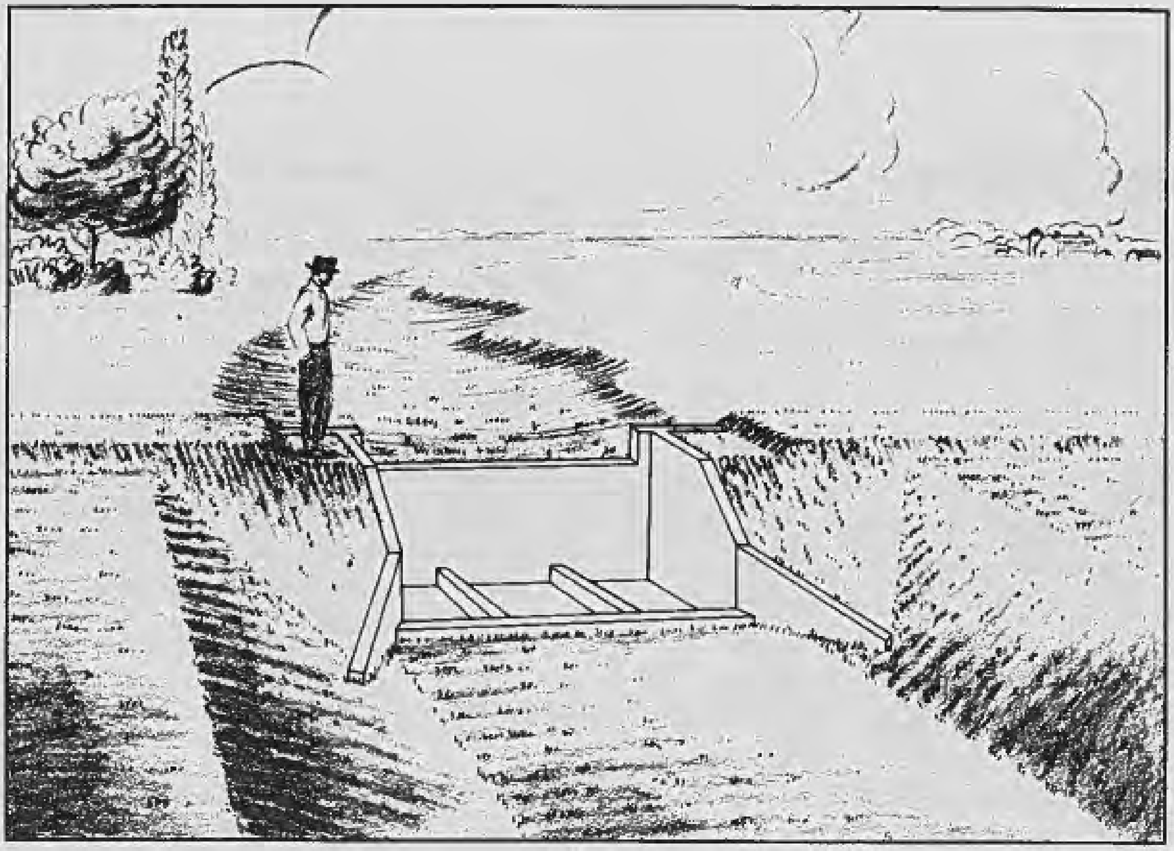
Water Quality: The following effects on water quality should be considered.

1. Ability of structure to trap sediment and sediment attached substances carried by runoff.

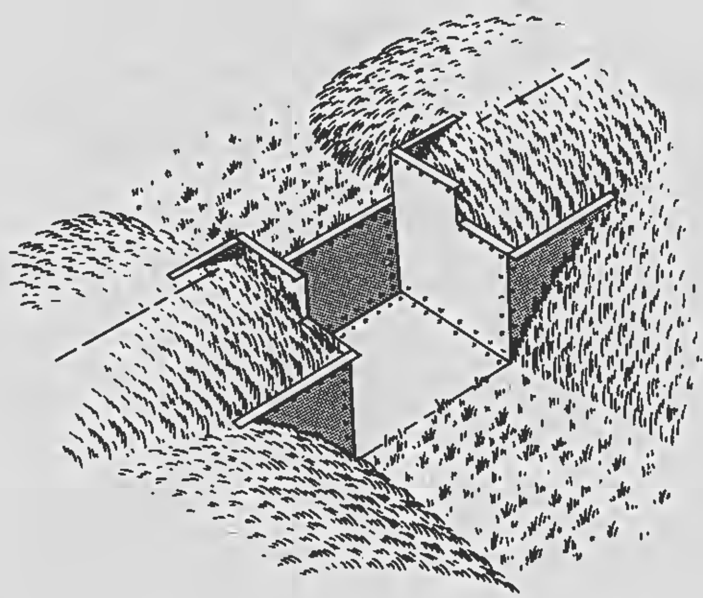
2. Effect of structure on the susceptibility of downstream stream banks and stream beds to erosion.

3. Effects of the proposed structure on the movement of dissolved substances to ground water.

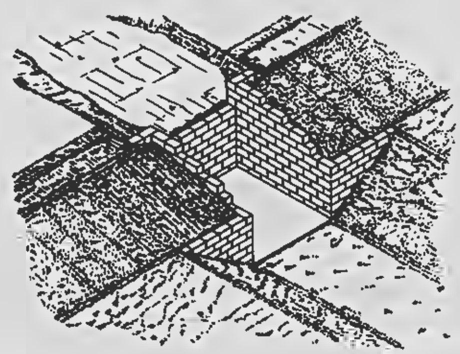
4. Effects on the visual quality of downstream water resources.



Reinforced concrete



Prefabricated metal



Concrete block

Figure 18 **—** Straight Drop Spillways

Design Criteria

Design and specifications should be prepared for each structure on an individual job basis, depending on its purpose and site conditions.

Capacity: Spillway capacity shall be adequate to pass, without damage to the structure, the overflow expected from a design storm commensurate with the purpose of the structure. Where a grade stabilization structure is part of an improved water conveyance system, the design storm shall be equal to or greater than that used for the channel improvement, i.e., channel modification, field ditch, grassed waterway, etc.

Peak runoff values used in determining the capacity requirements may be determined as outlined in Appendix B or by other accepted methods.

Design velocities and capacities shall be determined by using Manning's formula for open channel flow or other appropriate and accepted procedures. Design velocity computations will be based upon a roughness coefficient (n) commensurate with the type of channel lining to be used. Design velocities will be in the safe range for the type of channel linings used.

Structures which involve the retarding of floodwater or the impoundment of water shall be designed using the criteria set forth in the standard for sediment basins.

Where practical, a chute or drop may be used in conjunction with a vegetated spillway. In this case, the structure capacity without freeboard will be that portion of the total discharge that is not carried by the vegetated spillway with the upstream water surface just at the point of overtopping the earth dam embankment.

Freeboard: The freeboard capacity of the spillway will be the discharge through the spillway when the water surface is just at the point of overtopping the structure. The minimum freeboard peak flow shall be determined by increasing the design peak flow by 20 percent.

Design Aids

The following formulas are accepted for calculating the discharge from straight drop spillways:

1. $Q = 3.33\,(L - 0.2d)d^{3/2}$

   where Q = discharge in cfs
   L = length of weir in feet
   d = design depth of weir (freeboard is not included)

2. $Q = CL\left[H + \frac{Va^2}{2g}\right]^{3/2} = \frac{3.1\,L\,h^{3/2}}{(1.10+0.01F)}$

   where Q = discharge in cfs
   L = length of weir in feet
   H = head of weir in feet
   h = total depth of weir in feet (includes freeboard)
   Va = mean velocity of approach in fps
   g = acceleration of gravity in feet per second^2
   C = discharge coefficient
   F = overfall or drop over weir crest in feet

Table 10 gives discharge values for formula number 1.

With high tailwater, the weir will become submerged and free discharge must be modified accordingly. Figures 19 and 20 give the information that is needed to determine the effect of submergence of a weir in accordance with the following formula:

Qs = RQf

where Qs = submerged discharge in cfs
Qf = free discharge in cfs
R = ratio Qs / Qf

Specifications

Construction operations shall be carried out in such a manner that erosion and air and water pollution will be minimized. State and local laws concerning pollution abatement shall be followed.

The foundation for structures shall be cleared of all trees, brush, stumps, and other objectionable materials prior to the installation of the structures.

Structures shall be installed according to lines and grades shown on the plan. Materials used in construction shall be of a permanency commensurate with the design frequency and life expectancy of the practice.

Earth fill, when used as a part of the structure, shall be placed according to the construction specifications for sediment control basins.

All disturbed areas shall be stabilized to prevent erosion. Sodding, seeding, fertilizing, and mulching shall conform to the recommendations in the standard and specifications for seeding and planting.

Table 10 — Chart Showing Capacity of Weirs (cfs)

Head	Length of Weir Opening "L" in Feet										
"d"	4	6	8	10	12	14	16	18	20	22	24	26
1'—6"	23	35	47	59	72	84	96	108	121	133	145	157
2'—0"	34	53	72	90	109	128	147	166	185	203	222	241
2'—6"	46	72	99	125	151	178	204	230	257	283	309	336
3'—0"	59	93	128	163	197	232	266	301	336	370	405	439
3'—6"	72	116	159	203	246	290	334	377	421	464	508	552
4'—0"	85	139	192	245	298	352	405	458	511	565	618	671
4'—6"	99	162	226	289	353	416	480	544	607	671	734	798
5'—0"	112	186	261	335	410	484	558	633	707	782	856	931
5'—6"	125	210	296	382	468	554	640	726	812	898	984	1070

Capacity of Weirs — $Q = 3.33\,(L - 0.2d)d^{3/2}$

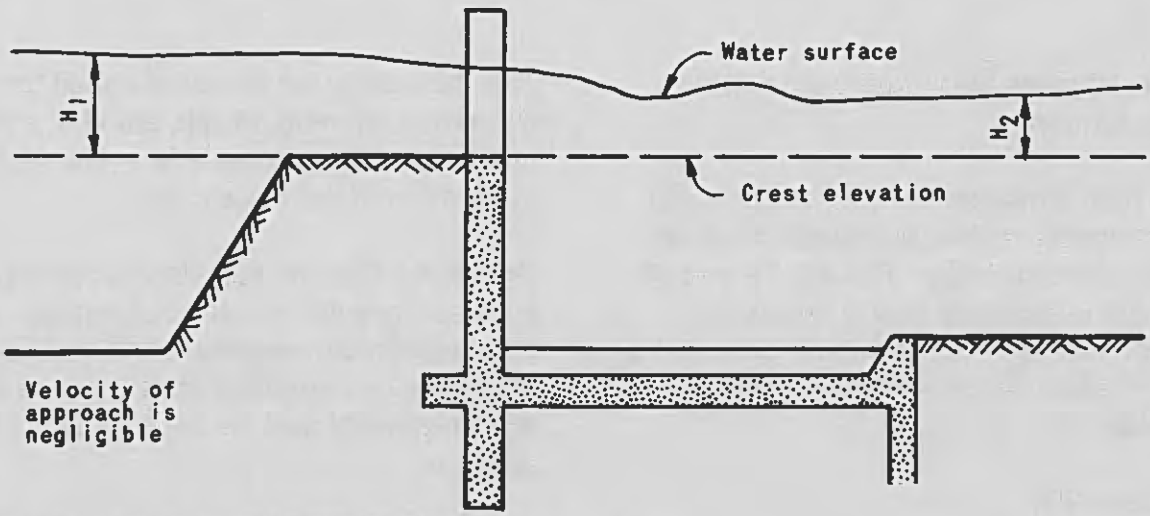


Figure 19 — Submerged Drop Spillway

H_2 = submergence = difference in elevation between tailwater and crest of weir in feet.

H_1 = upstream head on weir with negligible velocity of approach.

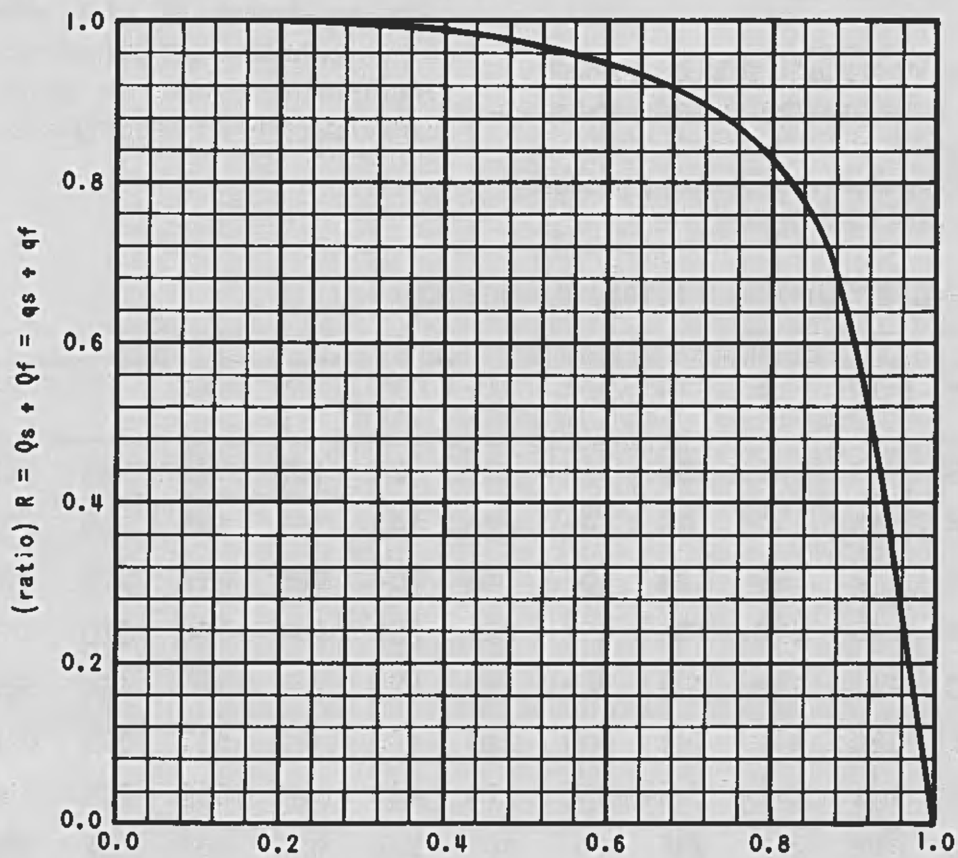


Figure 20 — Submergence Ratio H_2/H_1

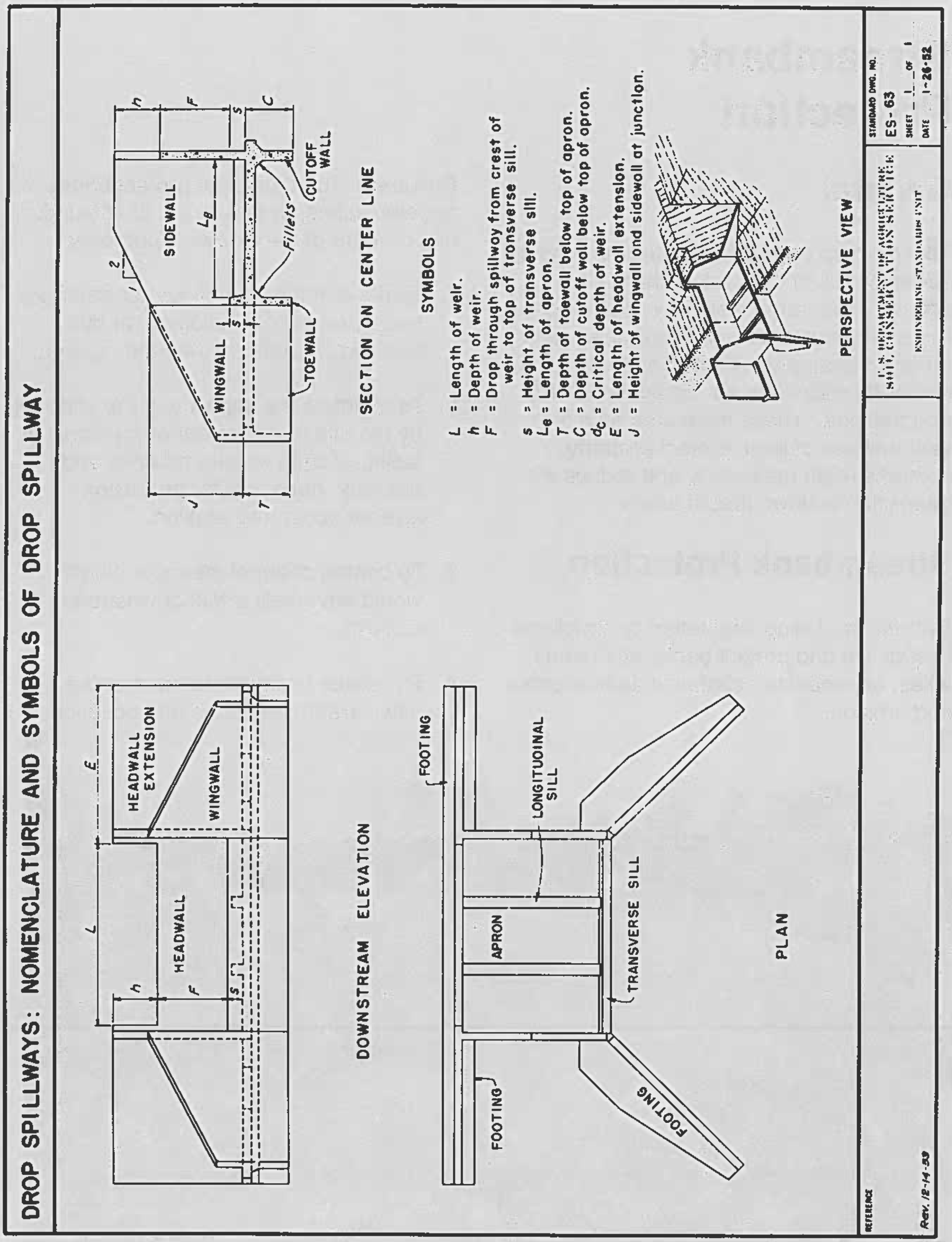

DROP SPILLWAYS: NOMENCLATURE AND SYMBOLS OF DROP SPILLWAY
HEADWALL
HEADWALL EXTENSION
WINGWALL
DOWNSTREAM ELEVATION
FOOTING
LONGITUDINAL SILL
APRON
TRANSVERSE SILL
PLAN
SIDEWALL
Fillets
CUTOFF WALL
TOEWALL
SECTION ON CENTER LINE
SYMBOLS
L = Length of weir.
h = Depth of weir.
F = Drop through spillway from crest of weir to top of transverse sill.
s = Height of transverse sill.
L_B = Length of apron.
T = Depth of toewall below top of apron.
C = Depth of cutoff wall below top of apron.
d_c = Critical depth of weir.
E = Length of headwall extension.
J = Height of wingwall and sidewall at junction.
PERSPECTIVE VIEW
U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE
ENGINEERING STANDARDS UNIT
STANDARD DWG. NO. ES-63
SHEET 1 OF 1
DATE 1-26-52
REFERENCE
Rev. 12-14-53

Figure 21

Streambank Protection

General

This practice consists of protecting eroding streambanks or excavated channels against scour and erosion by using vegetative or structural means, or a combination thereof. Examples of commonly used structural measures are riprap, concrete, and gabions. These measures help prevent the loss of land, protect property, control stream meanders, and reduce silt deposition in downstream areas.

Streambank Protection

Definition: Using vegetation or structures to stabilize and protect banks of streams, lakes, or excavated channels against scour and erosion.

Purpose: To stabilize or protect banks of streams, lakes, or excavated channels for one or more of the following purposes:

1. To prevent the loss of land or damage to utilities, roads, buildings, or other facilities adjacent to the eroding area.

2. To maintain the capacity of the channel by the use of revetment or mechanical facing of ditch or streambanks and auxiliary measures for protection against scour and erosion.

3. To control channel meander which would adversely affect downstream facilities.

4. To reduce sediment loads causing downstream damages and pollution.

Streambank protection is most commonly provided by rock riprap.

5. To improve the stream for recreation or as a habitat for fish and wildlife.

Conditions Where Practice Applies: This practice applies to streams, lakes, or excavated channels where the banks are subject to erosion from the action of water, ice or debris or to damage from vehicular traffic.

It applies where streambank erosion causes damage to land, water resources or real property. It also applies to controlling erosion on shorelines where the problem can be solved with simple structural measures, vegetation, or upland erosion control practices. It is applicable where failure of structural measures will not create a hazard to life or result in serious damage to property.

Planning Considerations

Water Quantity: The following effects on water quantity should be considered.

1. Effects on the water budget, especially on volumes and rates of runoff, infiltration, deep percolation, and ground water recharge.

2. Effects on downstream flows and aquifers that affect other uses and users.

Water Quality: The following effects on water quality should be considered.

1. Filtering effects of vegetation on movement of sediment, and sediment-attached and dissolved substances.

2. Effects on erosion and movement of sediment, and soluble and sediment-attached substances carried by runoff and streamflow.

3. Effects on the visual quality of onsite and downstream water resources.

4. Effects of construction and vegetation establishment on quality.

5. Effects of changes in water temperatures.

6. Short-term and long-term effects on wetlands and water-related wildlife habitats.

Design Criteria

Since each reach of channel, lake or stream is unique, measures for streambank and shoreline protection must be installed to a plan adapted to the specific site.

Streambank protection measures will be designed to withstand the velocities and forces to which they are subjected. They will be designed according to procedures contained in SCS Technical Release 25 or Highway Research Report 108 (Tentative Design Procedures for Riprap-lined Channels). Procedures contained in *Bank and Shore Protection in California Highway Practice*, *November 1970* may also be used.

On uniform streams with drainage areas of 640 ac. or less and stream velocities of 12 fps or less, procedures contained in Chapter 16 of the SCS Engineering Field Handbook for Conservation Practices may be used. Stream velocities can be determined using Manning's Equation with appropriate values of "n".

Channel flow restrictions such as narrow cross sections, rock ledges, culverts, bridges, etc., will necessitate a detail water surface profile determination for realistic capacity computations. All channels which have restrictions mentioned above, regardless of drainage area size, shall have detail water surface profile calculations. The consideration of changes in velocity head between sections may be disregarded when they are insignificant.

Structural measures will be designed to extend to the elevation of peak flow from a 5-yr.—24-hr. storm or bank-full flow, whichever is the least. However, if structural measures do not extend to the top of the bank, they will be stable at bank-full flows.

Toe scour will be controlled by either natural or artificial means or the bank protection will be constructed to a depth below the anticipated lowest depth of bottom scour. The minimum depth of scour protection below the stream bottom will be 1.0 ft. for streambank protection measures less than 4 ft. high, and 2.0 ft. for those measures greater than 4.0 ft. high.

Measures will begin and end at stabilized or controlled points on the stream. Ends of revetments, bulkheads, jetties and groins shall be keyed into the bank a minimum depth equal to the height of the bank protection.

Needed channel clearing to remove stumps, fallen trees, debris and bars which force the streamflow into the streambank shall be an initial element of the work.

Control of surface runoff and internal drainage shall be considered in all designs.

Channel alignment changes will meet the requirements of the standard for open channels.

Vegetative protection shall be considered on the upper portions of eroding banks and especially on those areas which are subject to infrequent inundation. For uniform streams with drainage areas of 640 ac. or less, the allowable permissible velocities shall be as established in Table 4 of the standard for grassed waterways.

Vegetative measures shall conform to requirements contained in the applicable standard for seeding and planting. Side slopes will be no steeper than those shown below.

Material	Side Slope
Sand or silt with clay binder	2:1
Heavy clay or silty clay	1 1/2:1
Gravel, clean	2:1
Sand, clean	1:1
Solid rock	1/4:1
Loose rock or cemented gravel (cut)	1:1

All streambank protection measures shall be compatible with improvements planned or being carried out by others.

The following is a partial list of elements that may be included in a plan for streambank protection:

1. Removal of fallen trees, stumps, debris, minor ledge outcroppings, and sand and gravel bars that may cause local current turbulence and deflection.

2. Removal of trees and brush that adversely affect the growth of desirable bank vegetation.

3. Reduction of the slope of streambanks to provide a suitable condition for vegetative protection or for the installation of structural bank protection.

4. Placed or dumped heavy stone, properly underlaid with a filter blanket, if necessary, to provide armor protection for streambanks.

5. Deflectors constructed of posts, piling, fencing, rock, brush, or other materials that project into the stream to protect banks at curves and reaches subjected to impingement by high velocity currents.

6. Artificial obstructions, such as fences, to protect vegetation needed for streambank protection or to protect critical areas from damage, stock trails, or vehicular traffic.

7. Reinforced concrete, masonry, sacked concrete, rock-filled wire mesh gabion baskets, concrete or wood cribs, piling, grouted rock riprap, precast paving blocks and other structures that provide armor protection to the streambank or deflect erosive flows.

8. Lining the streambank with vegetation, either with a vigorously growing shrub, grass, or trees, or a combination of them. For further information on individual species, see the standard for seeding and planting.

Environmental Criteria

Fish and Wildlife: Special attention shall be given to maintaining or improving habitat for fish and wildlife.

Landscape Resources: Consideration shall be given to the use of construction materials, grading practices, vegetation, and other site development elements that minimize visual impacts and maintain or complement existing landscape uses such as pedestrian paths, climate controls, buffers, etc.

Construction Activity: Where possible, streambank and shoreline protection measures will be designed such that construction activities can be performed from the bank. Erosion and sediment control measures such as diking, mulching, temporary seeding, etc. will be incorporated in the design.

Plans for the measure shall include provisions for disposal of woody material from clearing operations, excess excavated material, and other debris. Disposal methods and areas will be such that the material will be stable and cannot reenter the stream.

Operation and Maintenance

An operation and maintenance plan shall be prepared for streambank or shoreline protection measures. The plan shall include, as a minimum, the following items:

1. Provisions for annual inspections and inspections following every major storm event.

2. Repair, replacement or addition of structural or vegetative measures, where needed because of damaging high flows.

3. Removal of sediment bars, undesirable vegetative growth, or other stream obstructions that may be causing flow to be diverted into the protection measures.

Design Aids

Reference may be made to Figures 22 through 25 which provide details of different kinds of deflecting jetties.

Specifications

Measures and construction methods that protect fish and wildlife values shall be incorporated as needed and practicable. Special attention will be given to protecting and maintaining key shade, food, and den trees and to stabilization of disturbed areas.

The required removal of any trees and brush will be done in such a manner as to avoid damage to other trees and property.

Disposal of trees, brush, and other material will be done in such a way as to have the least detrimental effect on the environment.

Construction operations shall be carried out in such a manner that erosion and air and water pollution will be minimized and held within legal limits.

The completed job should present a workmanlike finish.

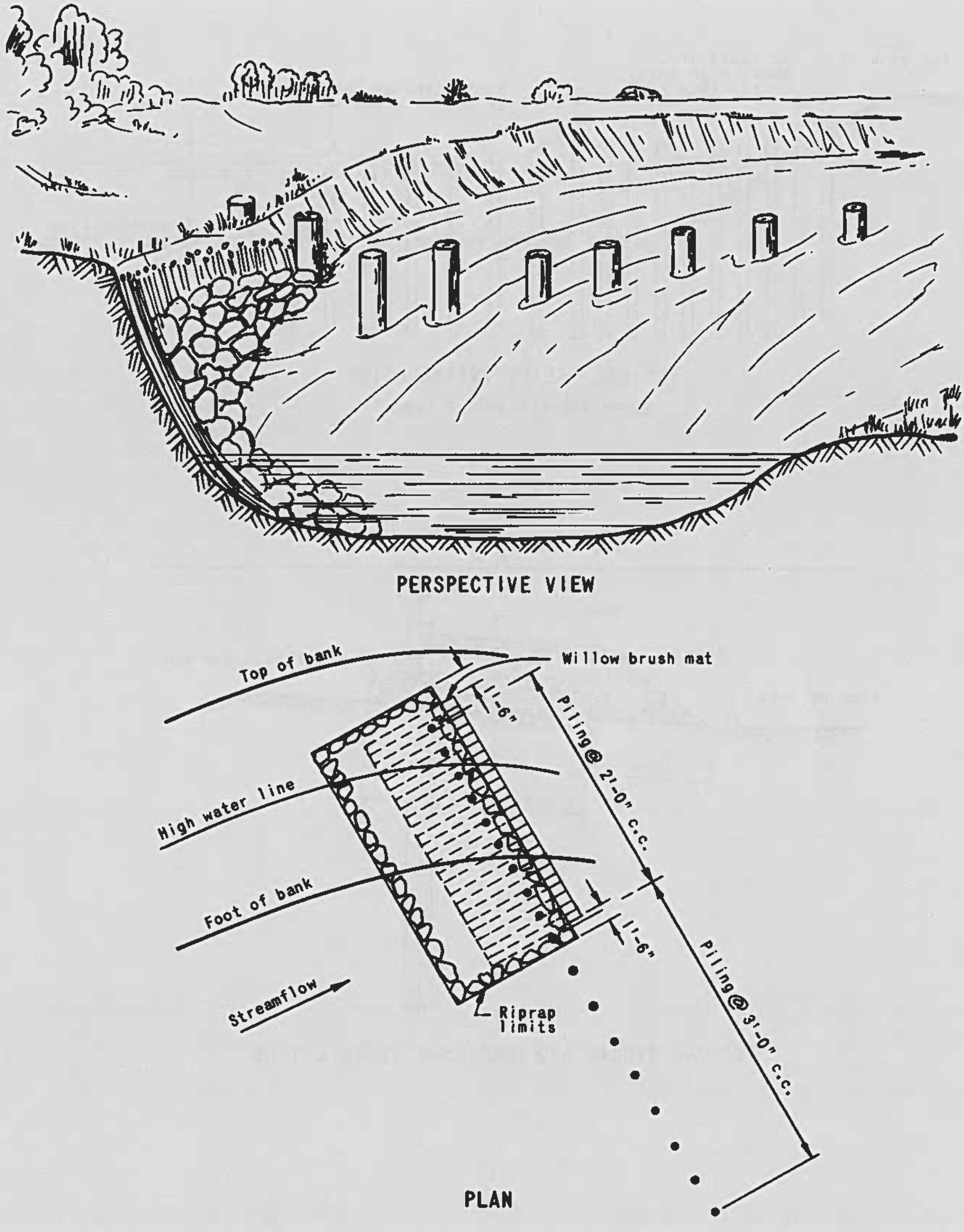
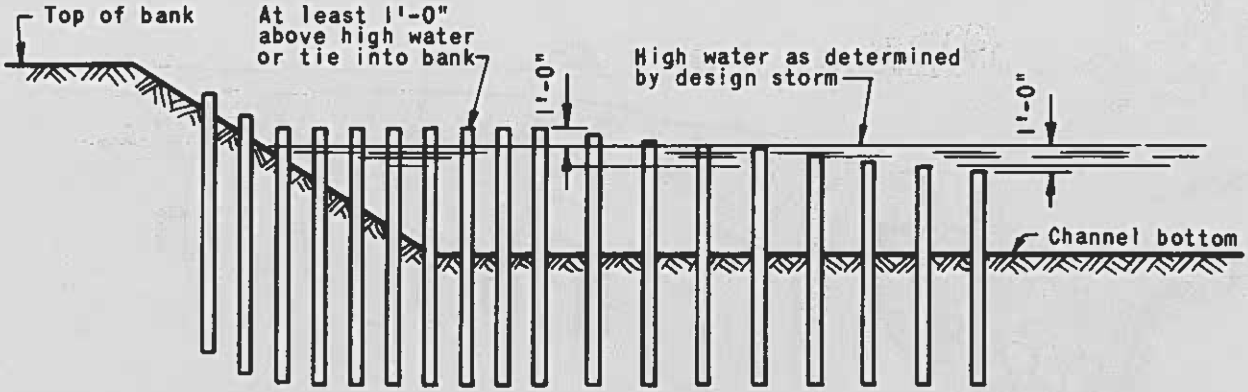
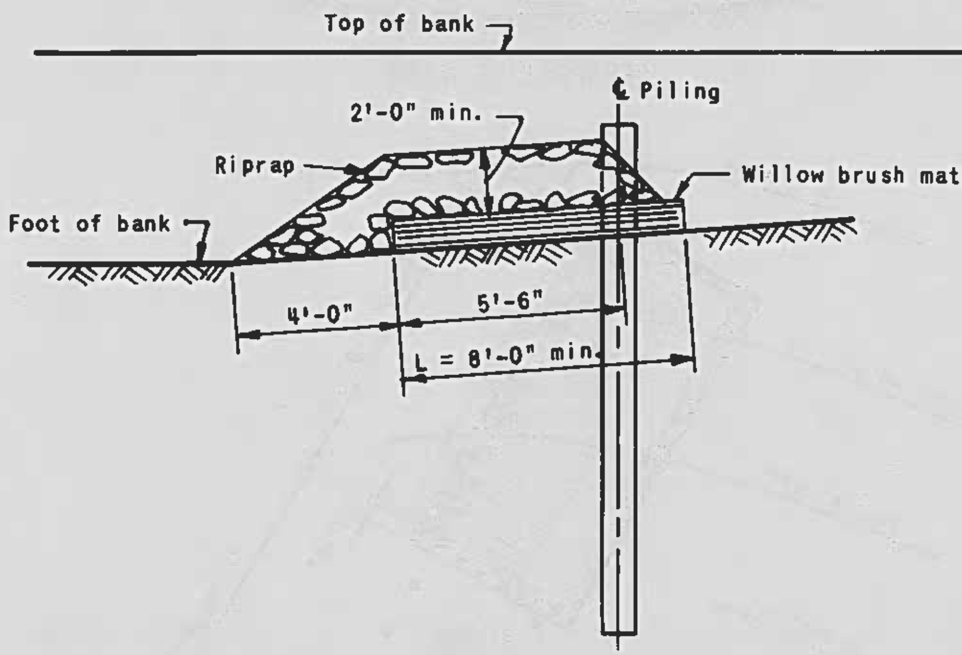


Figure 22 — Brush, Riprap, and Pile Deflecting Jetty

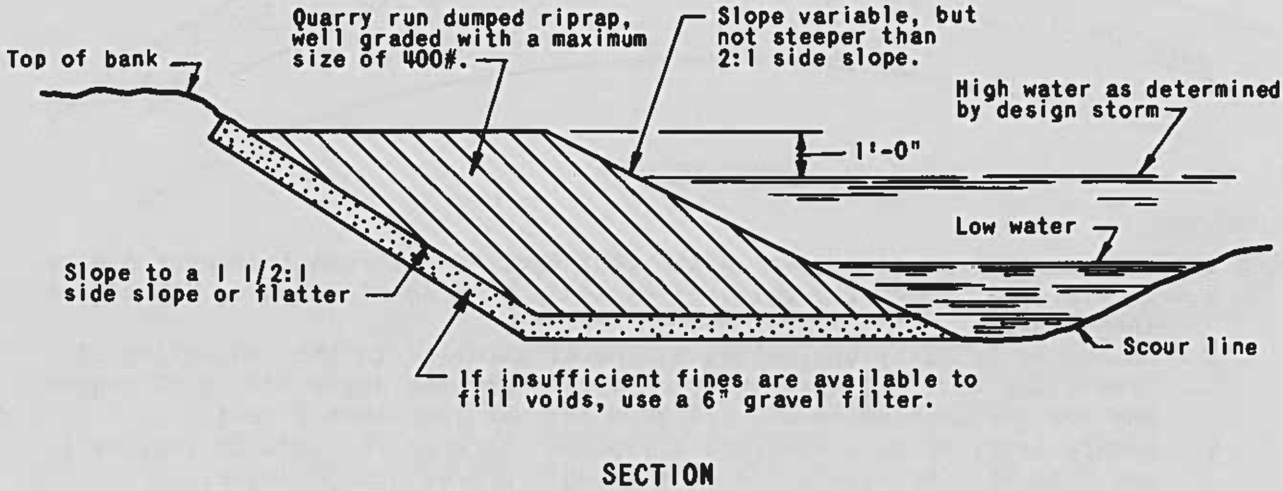


TYPICAL PILING INSTALLATION
BRUSH AND RIPRAP NOT SHOWN



TYPICAL RIPRAP AND BRUSH MAT INSTALLATION

Figure 23 — Brush, Riprap, and Pile Deflecting Jetty



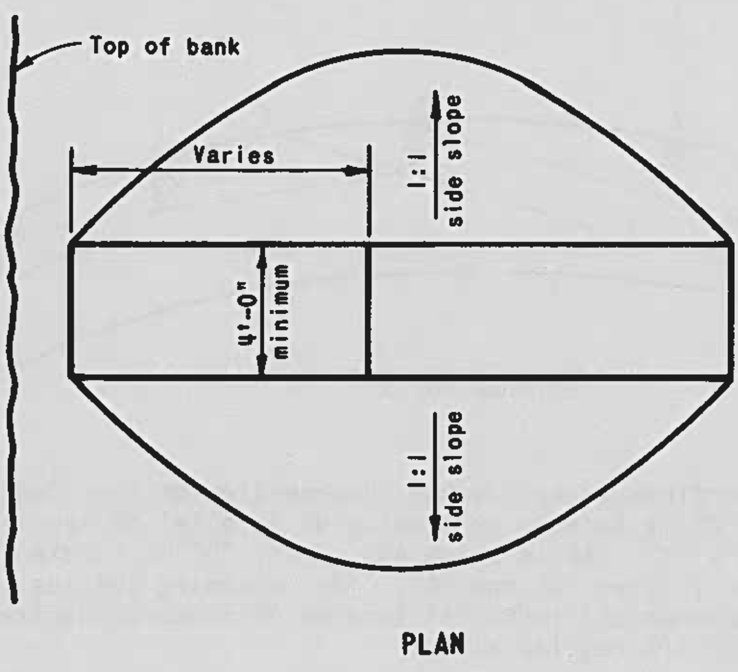
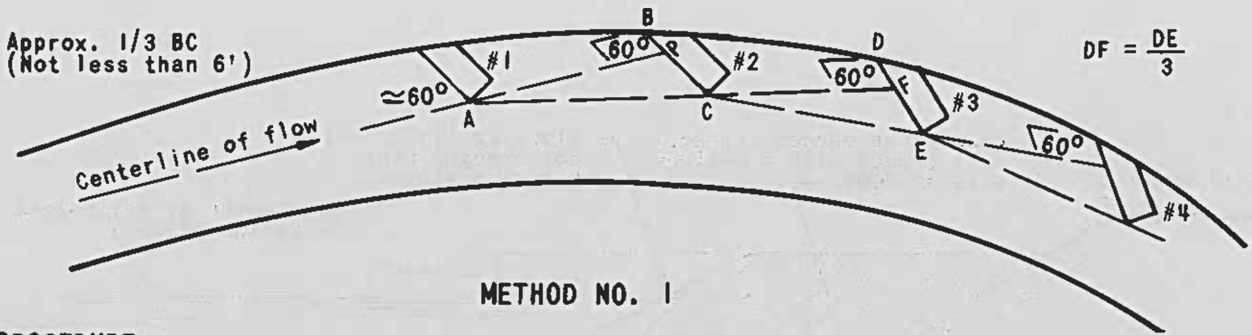


Figure 24 — Riprap Deflecting Jetties



METHOD NO. 1

PROCEDURE:

Step 1 - Draw centerline of stream in straight section upstream from eroded bank.

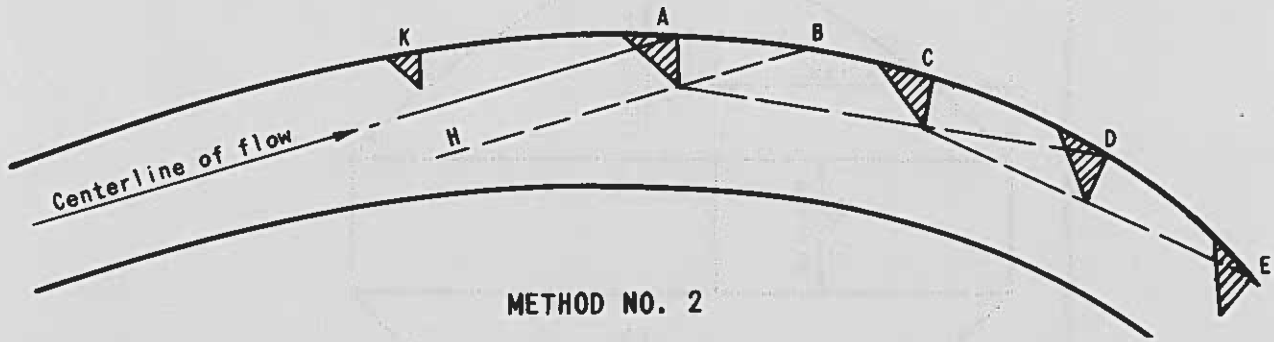
2 - Locate jetty #1 at the point of tangency or a short distance downstream therefrom.

3 - Locate jetty #2 by projecting a line AP parallel to the centerline of flow (step 1). The line BC is drawn so that the angle APB is 60 degrees and the distance BP equals 1/3 BC - but not less than 6 feet.

4 - Locate jetty #3 by projecting a line ACF through the ends of jetties 1 and 2 to DE. DF equals 1/3 DE and angle CFD equals 60 degrees.

5 - Successive jetties are located as per Step 4.

As a rule, jetty #1 is from 1/2 to 1/3 the length of the other jetties.



METHOD NO. 2

PROCEDURE:

Point "A", location of first jetty, is the intersection of the flow line and the eroding bank. Jetty "C" is located by drawing HB parallel to the flow line and across the toe of jetty "A". AC is twice AB. Jetty "D" is located projecting a line across the toe of jetties "A" and "C". The remaining jetties are located the same as "D". Supplementary jetty "K" located AC distance upstream from "A" should be approximately 1/2 regular size.

Generally, when curvature of the eroding bank exceeds 30 degrees (200 ft. radius or less), it is safer and more economical to use some type of revetment for protection instead of jetties.

Figure 25 — Method of Locating and Spacing Jetties

Open Channel

Definition: Constructing or improving a channel either natural or artificial, in which water flows with a free surface.

Purpose: To provide discharge capacity required for flood prevention, drainage, or other water management purposes.

Conditions Where Practice Applies:
This practice applies to open channel construction or modification of existing channels.

It also applies where stability requirements can be met, where the impact of the proposed construction on water quality, fish and wildlife habitat, forest resources, and quality of the landscape is evaluated and the techniques and measures necessary to overcome the undesirable effects are made part of any planned work, where an adequate outlet for the modified channel reach is available for discharge by gravity flow or pumping, and where excavation or other channel work does not cause significant erosion, flooding, or sedimentation.

Planning Considerations

Water Quantity:
Effects on components of the water budget, especially on volumes and rates of runoff and infiltration will be considered.

Water Quality: The following effects on water quality will be considered:

1. Effects of erosion and the movement of sediment and soluble and sediment-attached substances in runoff during and immediately after construction.
2. Effects of the use of chemicals during vegetation control.
3. Effects of changes in channel vegetation on downstream water temperature.
4. Potential for temporary and long-term effects on the visual quality of downstream waters.

Design Criteria

General: SCS Technical Release No. 25 "Design of Open Channels" contains methods of design applicable to this practice.

In selecting the location and design of channels, careful consideration shall be given to minimizing water pollution, damage to fish and wildlife habitat, and to protecting forest resources and the quality of the landscape. In considering requirements for construction and operation and maintenance, selected woody plants should be preserved. The overall landscape character, prominent views, and fish and wildlife habitat requirements must be considered.

Planned measures necessary to mitigate unavoidable losses to fish or wildlife habitat shall be included in the project. The quality of the landscape shall be maintained by both the location of channel works and plantings, as appropriate.

The alignment of channels undergoing modification shall not be changed to the extent that the stability of the channel or laterals thereto is endangered. Appendix B may be used for estimating the runoff expected from a drainage area. Other guides which may be used include Chapter 2 of the Soil Conservation Service Engineering Field Handbook and SCS Technical Release 55.

Capacity: The capacity for open channels shall be determined according to the purposes to be served. For uniform channels, Manning's equation may be used to determine capacity. The n value for aged channels shall be based on the expected vegetation, along with other retardance factors, considering the level of maintenance prescribed in the operation and maintenance plan prepared with the owners. For non-uniform channels the procedure contained in Technical Release 25 may be used.

Channel Cross Section: The required channel cross section and grade are determined by the design capacity, the materials in which the channel is to be constructed, and the requirements for maintenance. A minimum depth may be required to provide adequate outlets for subsurface drains, tributary ditches, or streams. Developments through which the channel is to be constructed must be considered in design of the channel section.

Design side slopes shall not be steeper than those shown below.

Material	Side Slope
Sand or silt with clay binder	2:1
Heavy clay or silty clay	1 1/2:1
Gravel, clean	2:1
Sand, clean	1:1
Solid rock	1/4:1
Loose rock or cemented gravel (cut)	1:1

Side slopes steeper than that shown will require mechanical streambank protection unless the existing streambank is stable and will not be disturbed nor the channel bottom deepened.

Alignment: The alignment of new channels must be such that there will be no sharp curves. The minimum radius of curvature will be as shown below unless shown stable for the criteria and procedure contained in Technical Release No. 25.

Water Surface Width (feet)	Minimum Radius (feet)	Approximate Degree of Curve (Degrees)
15 or less	400	14
15 to 35	600	10
35 or more	800	7

Channels outside the range of the above table and which are not stable using the procedures contained in Technical Release No. 25 will require special treatment. Sharp curves are needed in some locations to facilitate land use in the adjacent areas. Where this is necessary, streambanks should be protected in accordance with the standard for Streambank Protection.

Channel Stability: Characteristics of a stable channel are:

1. It neither aggrades or degrades beyond tolerable limits.

2. The channel banks do not erode to the extent that the channel cross section is changed appreciably.

3. Excessive erosion does not occur around culverts and bridges or elsewhere.

4. Excessive sediment bars do not develop.

5. Gullies do not form or enlarge due to the entry of uncontrolled surface flow to the channel.

All channel construction and improvement shall be in accordance with a design which can be expected to result in a stable channel which can be maintained at reasonable cost.

Drainage Area 640 Acres or Less: Design velocities shall not exceed those listed below without special protective measures (i.e. streambank protection and/ or stream channel stabilization). The material of the channel bed and bank being the most limiting will govern.

Bed and Bank Materials	Allowable Velocity ft/sec
Fine clean sands (SW, SP)	1.5
Silty sand (SM)	2.0
Coarse clean sand (SW, SP)	2.5
Alluvial silt, noncolloidal (ML)	2.5
Alluvial silt, colloidal (MH)	3.0
Clayey sand (SC)	3.0
Lean to moderately cohesive clay (CL)	3.0
Silty gravel (GM)	3.5
Fine clean gravel (GW, GP)	4.0
Clayey gravel (GC)	4.5
Stiff clay (CH)	4.5
Coarse clean gravel (GW, GP)	5.0
Cobbles and boulders	6.0
Weathered shale and hardpan	6.0

Drainage Area Exceeds 640 Acres: Channels with drainage areas greater than 640 acres shall be checked for stability under both aged and as built conditions as outlined below.

Aged condition — The channel shall be designed to be stable for an aged condition. The average velocity or tractive force shall be determined for both the design flow and bankfull flow. The channel shall be stable for both of these determinations when checked with the allowable limits contained in Technical Release No. 25. The "n" value for this calculation shall be based on the expected kind and density of vegetation and assuming good maintenance. In no case is it necessary to check channel stability for discharges greater than that from the 100-year frequency storm. The discharge used in stability analyses of channels having a controlled inflow shall be their design flow.

As built condition — The channel shall be designed to be stable under conditions existing immediately after construction. The average velocity or tractive force shall be determined for either the expected flow from a 10-year frequency storm on the watershed, or the bankfull flow. The channel shall be stable for either situation. The calculations need not be made for both conditions if the first situation checked is satisfactory.

The "n" value for the newly constructed channel shall be used. The "n" values of newly constructed channels in fine-grained soils and sands shall not exceed 0.025.

Bankfull flow is defined as the flow in the channel which creates a water surface that is at or near normal ground elevation for a significant length of a channel reach. Excessive channel depth created by cut through high ground, such as might result from realignment of the channel, should not be considered in determinations of bankfull flow.

The allowable velocity in the newly constructed channel may be increased by a maximum of 20 percent to reflect the effects of vegetation to be established under the following conditions:

1. The soil and site in which the channel is to be constructed are suitable for rapid establishment and support of erosion controlling vegetation.

2. The species and method of establishment of erosion controlling vegetation adaptable to the area are known and have been proven satisfactory.

3. The channel design includes detailed plans for establishment of vegetation on the channel side slopes.

Appurtenant Structures: The channel design shall include all structures required for proper functioning of the channel and its laterals, as well as travel ways for operation and maintenance. Inlets and structures needed for entry of surface and subsurface flow into channels without significant erosion or degradation shall be included in the channel design. If needed, protective structures or treatment shall be used at junctions between channels to insure stability at these critical locations.

The effect of channel work on existing culverts, bridges, buried cables, pipelines, and inlet structures for surface and subsurface drainage on the channel and laterals thereto shall be evaluated to determine the need for modification or replacement.

Culverts and bridges that are modified or added as part of channel projects shall meet reasonable standards for the type of structure and shall have a minimum capacity equal to the design discharge.

Disposition of Spoil: Spoil material from clearing, grubbing, and channel excavation shall be disposed of in a manner that will:

1. Not confine or direct flows so as to cause instability when the discharge is greater than the bankfull flow.

2. Provide for the free flow of water between the channel and flood plain unless the valley routing and water surface profile are based on continuous dikes being installed.

Specifications

Measures and construction methods that protect fish and wildlife values shall be incorporated as needed and practical. Special attention will be given to protecting and maintaining key shade, food, and den trees and to stabilization of disturbed areas.

Removal of any trees and brush required will be done in such a manner as to avoid damage to other trees and property.

Channels shall be excavated to the line and grades shown on the drawings. The excavated surfaces shall be reasonably smooth. Excavation shall be done in a manner which will not restrict flow in existing channels.

Material excavated from the channel shall be disposed of in the locations and in the manner shown on the drawings. In reaches involving realignment of existing channels, the upstream ends of segments of the old channel that are cut off by the new alignment shall be filled to ground level unless otherwise specified.

Spoil will be placed in a manner to maintain the stability of the streambanks and with consideration of the existing and future land use of the adjacent area.

All combustible refuse shall be burned or buried or disposed in such a way as to have the least detrimental effect on the environment. When buried, all roots, brush, stumps, stones, and similar material shall be placed a minimum of 18-inches below the elevation of the finished grade. All work shall be done in such a manner that erosion and air and water pollution will be minimized and held within legal limits. This shall be done by:

1. Placing spoil in a location to prevent its sloughing or washing into the channel or water course.

2. Keeping chemicals, fuel, lubricants, sewage and waste materials out of channel and drainage ways.

3. Limiting the use of excavating equipment to areas outside the channel and drainage ways except to those few times when no other alternative is possible.

4. Establish vegetation on all disturbed areas as soon as possible after exposure or disturbance, especially channel banks.

5. Fell trees away from stream and keep slash out of water courses.

Underground Outlet

Definition: A conduit installed beneath the surface of the ground to collect surface water and convey it to a suitable outlet.

Purpose: To dispose of excess water from diversions, subsurface drains, surface drains, or other concentrations without causing damage by erosion or flooding.

Conditions Where Practice Applies: This practice applies where:

1. Excess surface water needs to be disposed of.

2. A buried outlet is needed for diversions, or similar practices.

3. An underground outlet can be installed that will safely dispose of excess water.

4. Surface outlets are impractical because of stability problems, climatic conditions, land use, or equipment traffic.

Effects on Water Quantity and Quality

This practice will have a negligible effect on the quantity of surface and ground water.

There may be a decrease in the sediment delivered to the receiving waters because there is no bank and channel erosion with the flow in the underground outlet. There is reduced infiltration of water within the reach the underground outlet occupies. This may reduce slightly the amount of soluble substances which percolate toward the ground water. Any substances which enter the underground outlet will be delivered to the receiving waters.

Design Criteria

Capacity: The underground outlet shall be designed, alone or in combination with other practices, with adequate capacity to insure that the diversion, or other practices function according to the standard for the specific practice. For example, an underground outlet can be used in combination with a grassed waterway or a surface drain to carry part of the design flow. The capacity of the underground outlet for natural basins shall be adequate for the intended purpose without causing excessive damage to vegetation or improvements.

Procedures contained in the standard for culverts may be used to determine the capacity of short sections of underground outlets. Longer sections of conduit or those containing bends or other restrictions should be designed in accordance with accepted hydraulic engineering methods.

Inlets: Inlets can be drop inlets, perforated risers, hood inlets with baffle or canopy inlets. The capacity shall be adequate to provide the maximum design flow in the conduit. Flow-control devices shall be installed as necessary. Inlets must be durable material, structurally sound, and resistant to damage by rodents or other animals. Blind inlets can be used where they are effective. Collection boxes must be large enough to facilitate maintenance and cleaning operations. The inlet must have an appropriate trash guard to insure that trash or other debris entering the inlet passes through the conduit without plugging. It must also have an animal guard to prevent the entry of rodents or other animals.

Inlets will be designed with sufficient anchorage to prevent flotation, with a factor of safety of 1.5. Concrete inlets, 5 ft. or less in height, shall have a minimum wall thickness of 6 inches and be reinforced with one layer of welded wire fabric (6"x6"-8-gauge x 8-gauge minimum). All other concrete inlets will be designed according to accepted structural engineering methods.

When more than one inlet is used, the upper inlets will be designed to control the flow so discharge will not occur through the lower inlets.

Conduits: Underground outlets shall be continuous conduits, tubing or tile with a minimum diameter of 3 inches. They can be perforated or nonperforated, depending on the design requirements.

Pipe will meet the design requirements for internal pressure or vacuum and external loading. Thrust protection will be provided at elbows, bends and other fittings as necessary.

Conduits will be designed with a minimum velocity of 0.5 ft. per second when there is no hazard of siltation and with a minimum velocity of 1.4 ft. per second if siltation is a problem. If site conditions are such that minimum velocity cannot be met, provisions will be made for preventing sedimentation by use of filters or by collecting and periodically removing sediment from installed traps. Planned cleaning of lines with high-pressure jetting systems may also be considered.

Pipe will meet the requirements for external load, internal pressure, and installation. Pipe which is not pressure rated for water, such as corrugated polyethylene drainage tubing, will only be used when inlet controls, such as orifice plates, are used to restrict flow to that capacity at which the pipe just begins to flow full; determined by the equation:

$$Q = \frac{A_p \, 1.49 \, r^{2/3} \, S^{1/2}}{n}$$

where:

n= Manning's Roughness Coefficient

A_p= Area of the Pipe (sq. ft.)

r= Hydraulic radius = $\frac{\text{pipe diameter (ft.)}}{4}$

s= Conduit slope (ft./ft.)

When inlet control is not provided and pressure flow occurs, pipe with pressure ratings equal to or higher than design pressures will be used. Joints will be capable of withstanding the same pressures.

All systems will be designed to protect the pipe from excessive vacuum and surge pressures at elbows and other fittings when:

1. The pipe grade increases in the direction of flow by 10% or more, or

2. The pipe grade decreases in the direction of flow by 5% or more, or

3. The velocity in the pipe exceeds 15 ft. per second.

This protection may be provided by:

1. Designing pipe and joints to withstand the pressures, or

2. Installing vents or vacuum release valves where pipe grade increases, or

3. Installing pressure relief wells, pressure relief valves, or surge tanks where pipe grade decreases.

Outlets: Outlets will be designed to be stable and provide for release of flow at non-erosive velocities, as follows. Cantilever outlet sections, if used, shall be designed to withstand the cantilever load, and pipe supports shall be provided when needed. Pipe supports will be installed on all pipes where:

1. The exit velocity is 10 ft. per second or greater.

2. The length of the cantilever portion, measured along the pipe invert, is more than 35% of the total length of the last joint of pipe for pipe diameters 15 inches or less.

3. The length of the cantilever portion is more than 20% of the total length of the last joint for pipe diameters greater than 15 inches.

Energy dissipating outlet structures will be installed for all pipe outlets, unless the outlet is on rock, discharges into a permanent pool of water, or is located where erosion will not be a problem.

Small animal guards or gates will be installed as needed.

The invert elevation of all conduit outlets shall be a minimum of 1.0 ft. above the outlet channel.

Vegetation and Fencing: Vegetation of all disturbed areas shall be accomplished in accordance with standards for seeding and planting.

Fencing necessary to exclude livestock or humans for safety or protection of the practice, shall be constructed around inlets, outlets and along the pipe.

Operation and Maintenance

An operation and maintenance plan shall be developed for the installed underground outlet. The plan shall outline the minimum maintenance necessary to ensure the outlet functions for its design life.

As a minimum, the plan shall address the following:

1. Annual inspections and inspections after each major storm occurrence to assess the need for repair.

2. Removal of debris accumulations and sediment deposits at inlets and outlets.

3. Liming, fertilizing, and mowing of vegetation to maintain a healthy growth.

4. Repair of damaged inlets, outlets, trash racks, animal guards, fences, safety measures, and other items to maintain the system in good operating order.

5. Repair of eroding areas by revegetating or mechanical treatment such as riprap.

Specifications

Excavation for installation of underground outlets will be to the line and grade shown on the drawings. Trench width will be maintained to that shown on the drawings.

Soft compressible material found in the trench bottom will be removed by over excavation and the area backfilled with gravel or hand compacted earthfill.

Caution will be exercised when working in or around trenches with unstable side slopes. Workers will not enter any trench over 4 ft. deep without proper shoring or sloping of the trench walls to a minimum of 2h:1v above the 4 ft. depth.

Pipe, fittings and connectors will meet the requirements of the applicable ASTM specifications shown on the drawings, and will be installed according to the manufacturer's recommendations.

Inlet structures, outlet structures, thrust blocks (if used) and vents or relief wells (if used) will be installed as shown on the drawings.

Concrete used in construction of inlets, thrust blocks, and outlets shall be ready-mixed concrete (3000 psi - 6 bags/c.y. mix.), pre-bagged commercially available concrete mix, or be hand mixed on-site. Cement will be Type I or IA meeting requirements of ASTM C150 and aggregates will meet the requirements of ASTM C33. Coarse aggregate will be Size No. 57 or No. 67 for ready-mix and hand mixed concrete. Hand mixed concrete shall be mixed at a ratio of 1 part cement, 2 parts sand, and 3 parts coarse aggregate. Pre-bagged concrete mix will be mixed according to the manufacturer's recommendation. Mixing water will be clean and free of substances that would effect the strength or durability of the concrete. Concrete will be mixed to a consistency that will allow consolidation in the forms, but not so wet that aggregates separate from the mortar (approximately 3"-6" slump).

Concrete will be mixed and placed in the forms in a timely manner so that it does not begin to set prior to placement, or cold joints are not formed between successive layers. Forms shall be mortar tight and unyielding as concrete is placed.

Reinforcing steel shall be placed as shown on the drawings and held securely in place while concrete is placed.

Riprap for slope or pipe outlet protection, if required, will be commercially available limestone riprap or on-site field stone that has demonstrated its durability against weathering. Riprap size, gradation and details of installation will be as shown on the drawings.

Gravel for pipe bedding or as a filter under riprap, if required, will meet the grading and quality requirements shown on the drawings and will be installed as detailed on the drawings.

Selected backfill material shall be placed, in layers not exceeding 4" in thickness, around structures and pipe conduits at approximately the same rate on all sides to prevent damage from unequal loading, and hand compacted. Construction equipment shall not be permitted within 2 ft. of structures or conduits. Rocks and other sharp objects that may damage structures or pipe will be removed from the fill adjacent to the pipe or structure. When the surface level of the fill reaches 2 ft. above the pipe and at other locations more than 2 ft. from structures or pipe, the fill may be placed in 8-inch layers and compacted by a minimum of two passes with construction equipment.

The moisture content of fill material shall be adequate to permit the degree of compaction specified. The moisture content shall be sufficient to permit molding a firm ball when firmly squeezed in one's fist. The soil shall not be so wet that water runs out when squeezed nor so dry that the ball easily crumbles when slightly deformed. Water may need to be added if too dry.

Appropriate safety measures, such as warning signs, fencing, etc., will be installed as shown on the drawings.

Upon completion of construction, all disturbed areas shall be graded smooth and blend with the surrounding ground.

A protective cover of vegetation shall be established on all disturbed areas where soil and climatic conditions permit. Lime and fertilizer will be spread at the rate shown on the drawings and will be disked into the soil to a depth of 4 inches to prepare a seedbed. Seed and mulch will be spread at the rate shown on the drawings. Where soil or climatic conditions preclude the use of vegetation and protection is needed, nonvegetative means such as mulches or gravel may be used. In some cases, temporary vegetation may be used until conditions are right for establishment of permanent vegetation.

Construction operations shall be carried out in such a manner and sequence that erosion and air and water pollution will be minimized and held within legal limits.

Pipe Outlet Protection

Definition: Structurally lined aprons or other acceptable energy dissipating devices placed at the outlets of pipes.

Purpose: To prevent scour at storm water outlets and to minimize the potential for downstream erosion by reducing the velocity of concentrated storm water flows.

Conditions Where Practice Applies: Applicable to the outlets of all pipes where the velocity of flow at design capacity of the outlet will exceed the permissible velocity of the receiving channel or area. Table 4, of the grassed waterway standard may be used to determine permissible velocity.

Planning Considerations

The outlets of pipes are points of critical erosion potential. Storm water which is transported through man-made conveyance systems at design capacity generally reaches a velocity which exceeds the capacity of the receiving channel or area to resist erosion. To prevent scour at storm water outlets, a flow transition structure is needed which will absorb the initial impact of the flow and reduce the flow velocity to a level which will not erode the receiving channel or area.

The most commonly used device for outlet protection is a structurally lined apron. These aprons are generally lined with riprap, grouted riprap or concrete. They are constructed at a zero grade for a distance which is related to the outlet flow rate and the tailwater level. Criteria for designing such an apron are contained in this practice.

Where flow is excessive for the economical use of an apron, excavated stilling basins may be used. Acceptable designs for stilling basins may be found in Design Note 6 of the Soil Conservation Service.

The standard for lined waterways may be used to design outlet protection when water is discharged into road ditches or similar outlets.

Design Criteria

Structurally lined aprons at the outlets of pipes shall be designed according to the following criteria:

1. **Tailwater depth:** The depth of tailwater immediately below the pipe outlet must be determined for the design capacity of the pipe. Manning's Equation may be used to determine tailwater depth. If the tailwater depth is less than half the diameter of the outlet pipe, it shall be classified as a **Minimum Tailwater Condition**. If the tailwater depth is greater than half the pipe diameter, it shall be classified as a **Maximum Tailwater Condition**. Pipes which outlet onto flat areas with no defined channel may be assumed to have a **Minimum Tailwater Condition**.

2. **Apron length:** The apron length shall be determined from the attached curves according to the tailwater condition:

3. **Apron width:** If the pipe discharges directly into a well-defined channel, the apron shall extend across the channel bottom and up the channel banks to an

elevation one foot above the maximum tailwater depth or to the top of the bank (whichever is less).

If the pipe discharges onto a flat area with no defined channel, the width of the apron shall be determined as follows:

a. The upstream end of the apron, adjacent to the pipe, shall have a width three times the diameter of the outlet pipe.

b. For a **Minimum Tailwater Condition**, the downstream end of the apron shall have a width equal to the pipe diameter plus the length of the apron.

c. For a **Maximum Tailwater Condition**, the downstream end shall have a width equal to the pipe diameter plus 0.4 times the length of the apron.

4. **Bottom grade:** The apron shall be constructed with no slope along its length (0.0% grade). The invert elevation of the downstream end of the apron shall be equal to the elevation of the invert of the receiving channel. There shall be no overfall at the end of the apron.

5. **Side slopes:** If the pipe discharges into a well-defined channel, the side slopes of the channel shall not be steeper than 2:1 (Horizontal: Vertical).

6. **Alignment:** The apron shall be located so that there are no bends in the horizontal alignment.

7. **Materials:** The apron may be lined with riprap, grouted riprap, or concrete. The median sized stone for riprap shall be determined from the attached curves according to the tailwater condition. Riprap shall conform to the following requirements:

a. The riprap shall be composed of a well-graded mixture down to the one-inch size particle such that 50% of the mixture by weight shall be larger than the d_{50} size as determined from the design procedure. A well-graded mixture as used herein is defined as a mixture composed primarily of the larger stone sizes but with a sufficient mixture of other sizes to fill the progressively smaller voids between the stones. The diameter of the largest stone size in such a mixture shall be 1.5 times the d_{50} size.

b. The minimum thickness of the riprap layer shall be 1.5 times the maximum stone diameter but not less than 6 inches.

c. Stone for riprap shall consist of field stone or durable quarry stone of approximately rectangular shape. The stone shall be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering and it shall be suitable in all other respects for the purpose intended.

Rubble concrete may be used provided it has a density of at least 150 pounds per cubic foot.

d. A filter composed of graded aggregate or filter cloth may be required beneath the riprap.

Sample Problems Outlet Protection Design

Example 1

Given: An 18-inch pipe discharges 24 $ft.^3$/sec. at design capacity onto a grassy slope (no defined channel).

Find: The required length, width and median stone size (d_{50}) for a riprap-lined apron.

Solution:

1. Since the pipe discharges onto a grassy slope with no defined channel, a Minimum Tailwater Condition may be assumed. (Figure 26)

2. From the attached curves an apron length (La) of 20 feet and a median stone size (d_{50}) of 0.8 ft. are determined.

3. The upstream apron width equals three times the pipe diameter; 3 x 1.5 ft. = 4.5 ft.

4. The downstream apron width equals the apron length plus the pipe diameter; 20 ft. + 1.5 ft. = 21.5 ft.

Example 2

Given: The pipe in example No. 1 discharges into a channel with a triangular cross-section, 2 feet deep and 2:1 side slopes. The channel has a 2% slope and an "n" factor of .045.

Find: The required length, width and the median stone size (d_{50}) for a riprap lining.

Solution:

1. Determine the tailwater depth using Manning's Equation.

$$Q = \frac{1.49 \quad R^{2/3} \quad S^{1/2} \quad A}{n}$$

$$24 = \frac{1.49}{.045}\left[\frac{2d}{2\,(2^2+1)^{1/2}}\right]^{2/3}(.02)^{1/2}\,(2d^2)$$

where,
d = depth of tailwater
d = 1.74 ft.*

*Since d is greater than half the pipe diameter, a Maximum Tailwater Condition exists. (Figure 27)

2. From the attached curves, a median stone size (d_{50}) of 0.5 ft. and an apron length (La) of 41 ft. is determined.

3. The entire channel cross-section should be lined, since the maximum tailwater depth is within one foot of the top of the channel.

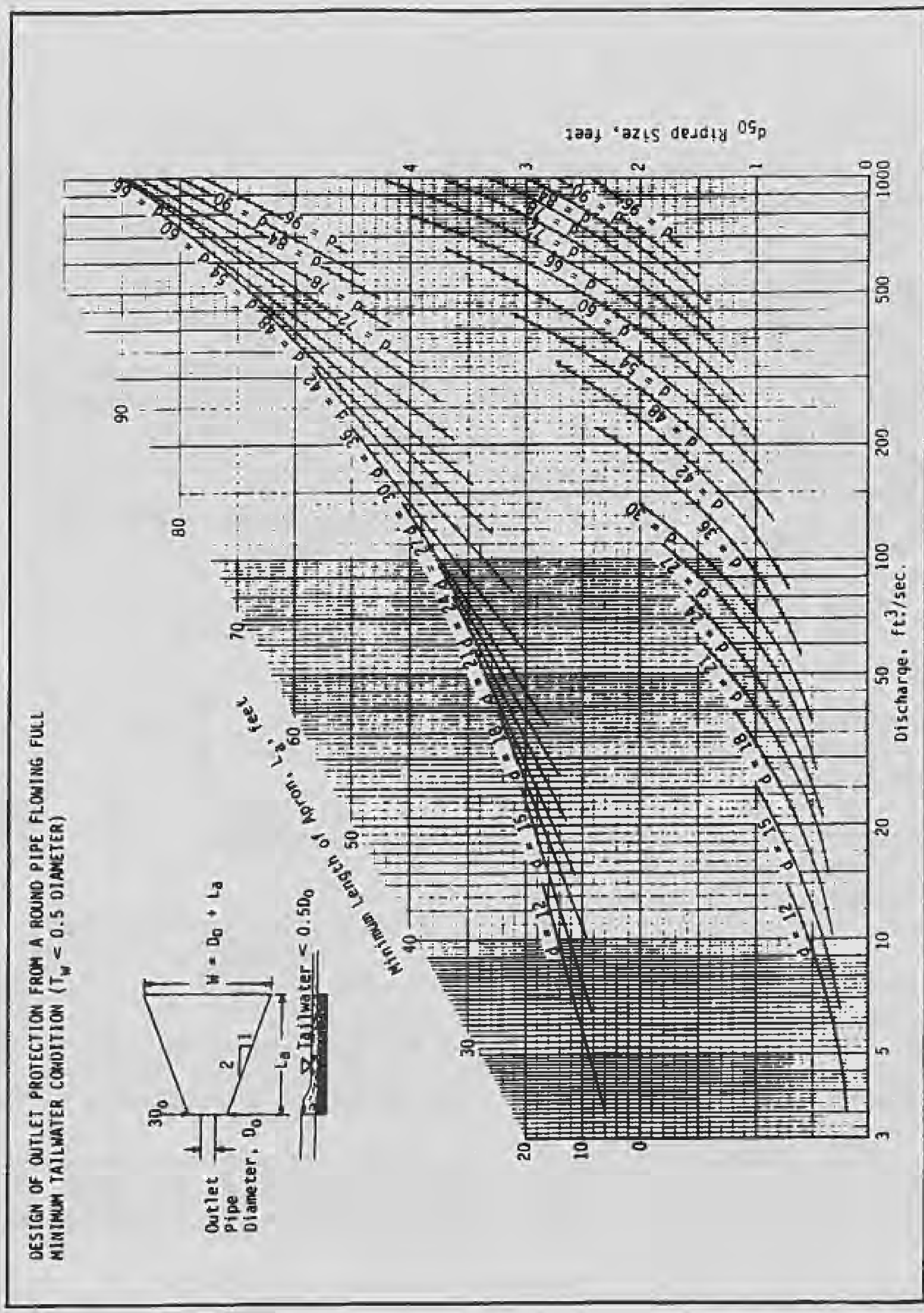


Figure 26 — Minimum Tailwater Condition

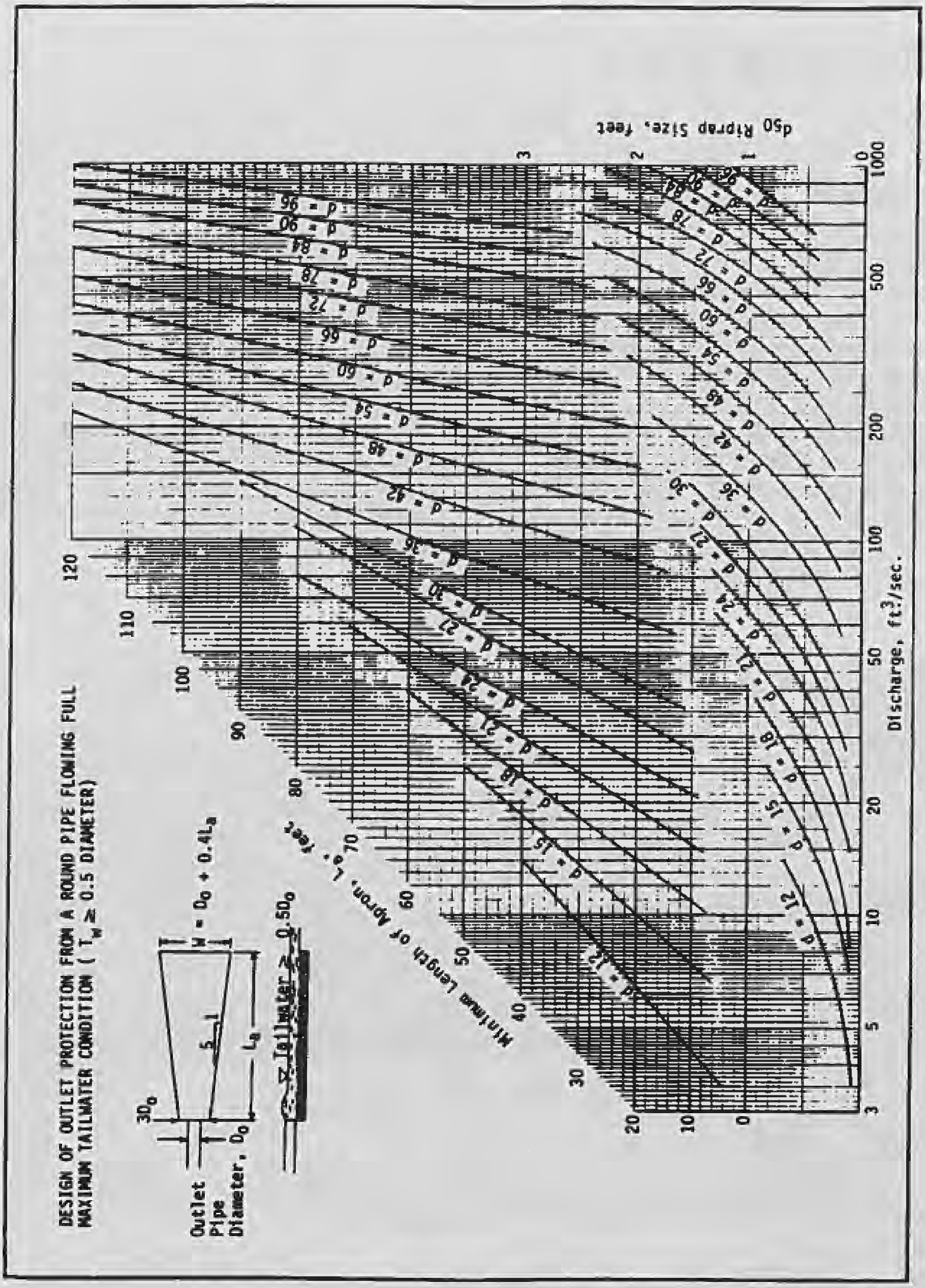


Figure 27 — Maximum Tailwater Condition

Retaining Walls

General

Retaining walls are used in areas where building activities create steep slopes that are unstable. They are commonly used around homes to protect driveways and yards. Extensive use is also made of retaining walls in road construction, where adequate area is not available for stable slope construction. These walls help stabilize steeply sloping land to permit use under stable conditions with minimum soil loss. Common construction materials are concrete, rock, cribbing, and ties.

Designs should be prepared by a registered professional engineer in accordance with procedures outlined in the book, Civil Engineering Handbook by Urquhart. Construction materials are to conform to the applicable ASTM standard. Construction is to be performed so that erosion and water and air pollution will be at a minimum. All construction should be in accordance with approved construction methods and procedures.

A crib-type retaining wall helps reduce erosion.

Three other types of retaining walls are shown in the following pictures.

A short wall made of railroad ties.

A poured concrete wall with drains.

A native rock wall.

Culverts

General

Culverts are pipe conduits constructed of steel, iron, concrete, aluminum, or other suitable material installed for the purpose of transporting surface runoff for short distances. The most common installation location is where roads cross natural drainage ways. Another use is at locations where the natural stream is placed in an underground pipe to permit use of an area for buildings, parking lots, etc.

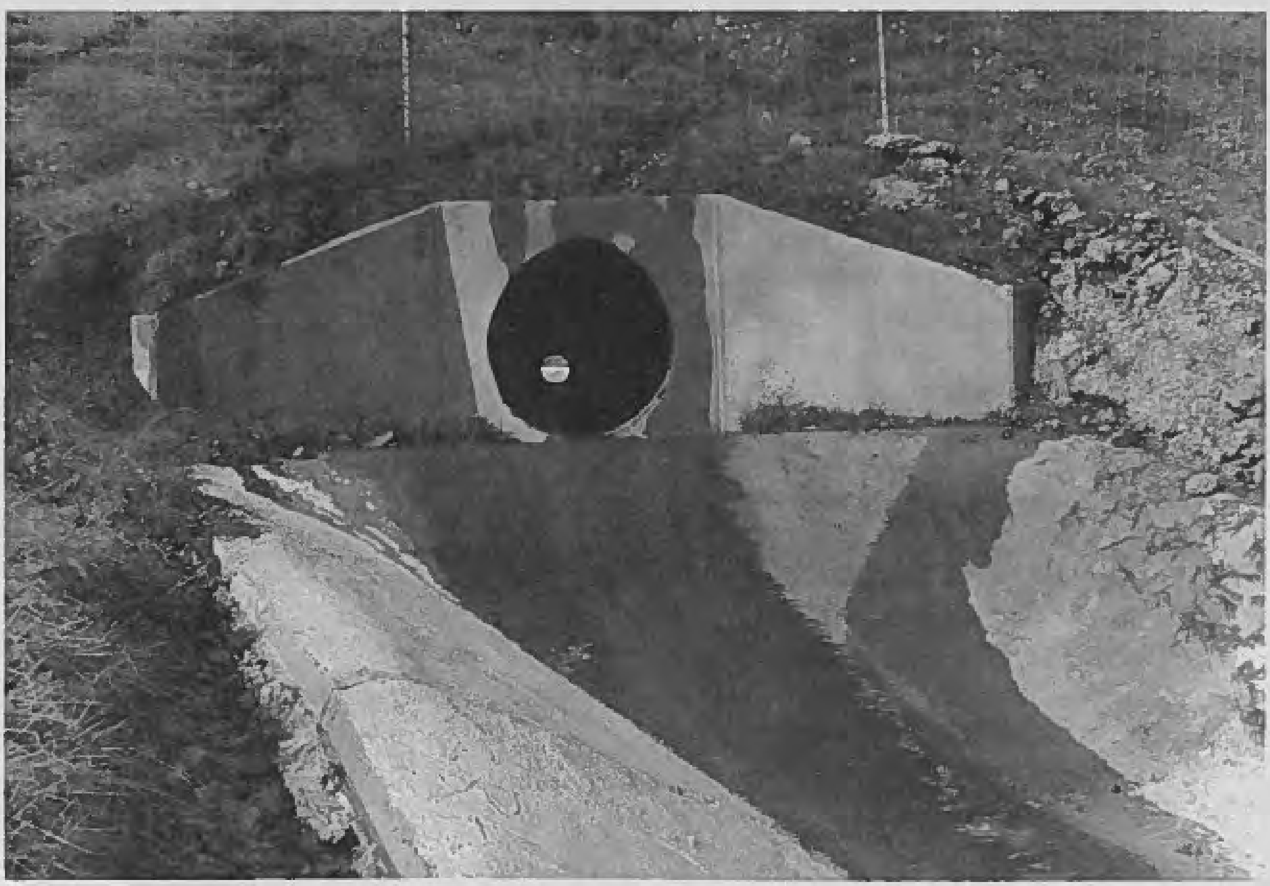
The storm frequency used for culvert design depends on the project and its location to other improvements. For example, a road culvert being installed in a mostly wooded area on a low traveled road may only require a 10-year storm frequency design. A culvert installed on a highly traveled road in an urban area may be designed on a 50- to 100-year storm frequency. The frequency of design should be selected based upon the hazard involved to life and property.

The following table provides suggested minimum frequency for the locations noted. It does not relieve the designer of making on-site evaluations and in-turn storm frequency determinations.

Table 11 — Culvert Design Storm Frequencies (Minimum)

Location	Design	Frequency
1 lane road (urban area)	10 year	24 hour
2 lane road (urban area)	25 year	24 hour
Parking lots	10 year	24 hour
Building sites	50 year	24 hour

Runoff can be determined by using procedures outlined in Appendix B. Figures 28 through 32 may be used for sizing corrugated metal and concrete culverts.



This well designed culvert conveys water underneath a new highway to help reduce erosion.

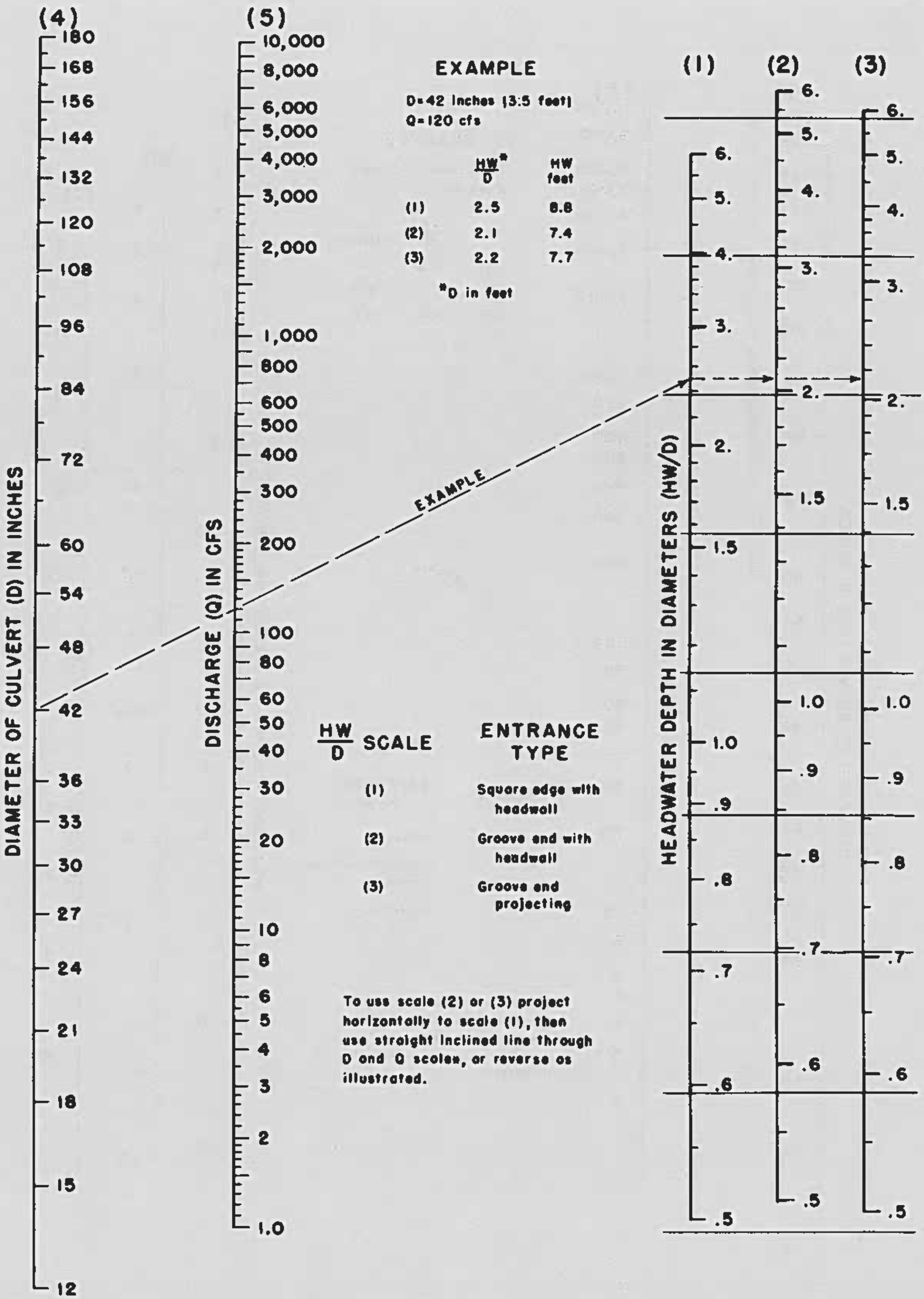


Figure 28 — Headwater Depth for Concrete Pipe Culverts with inlet Control (Ref. Hyd. Eng. Cir. No. 5, USBPR, 1965)

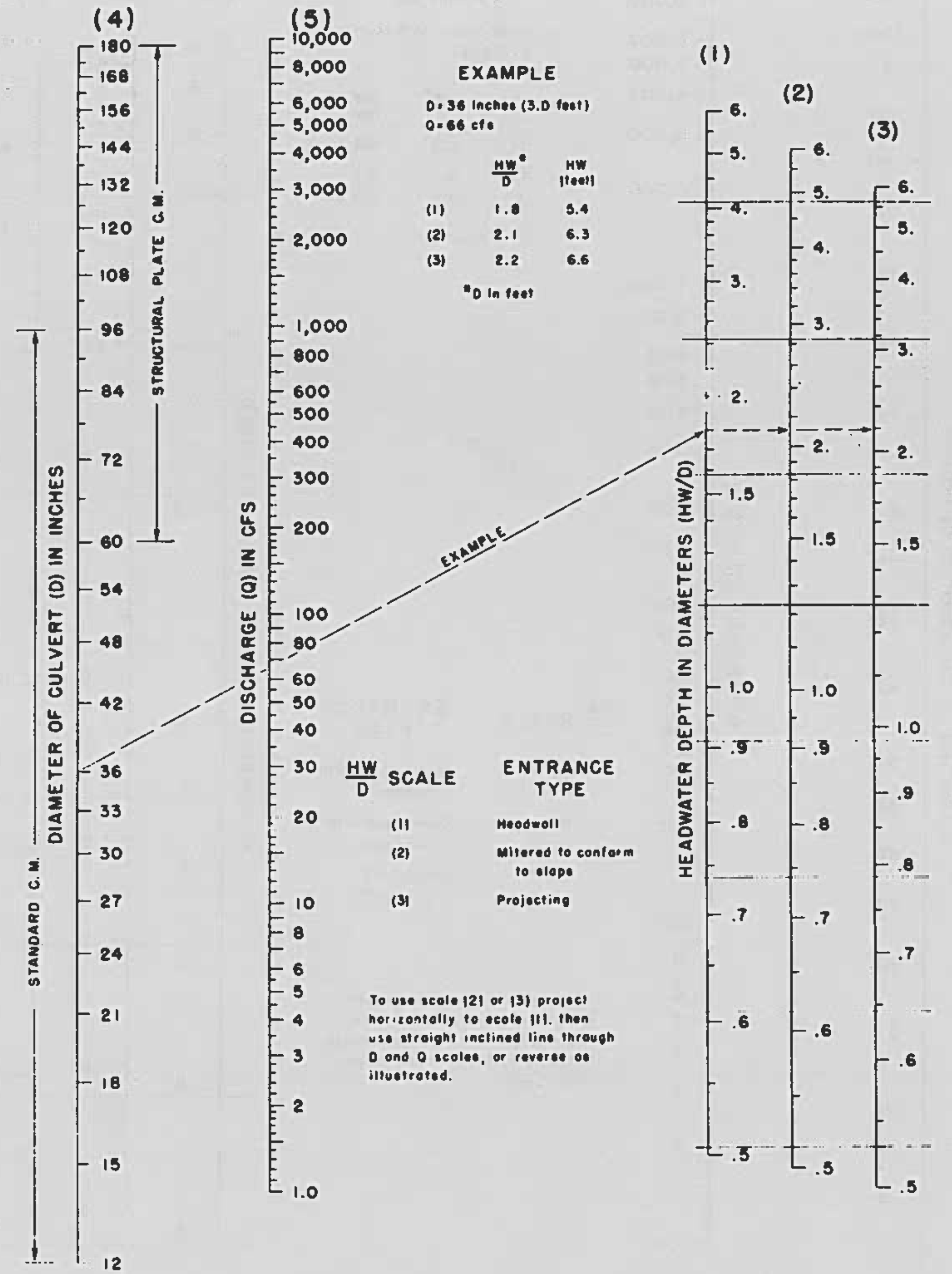


Figure 29 — Headwater Depth for CM Pipe Culverts with inlet Control (Ref. Hyd. Eng. Cir. No. 5, USBPR, 1965)

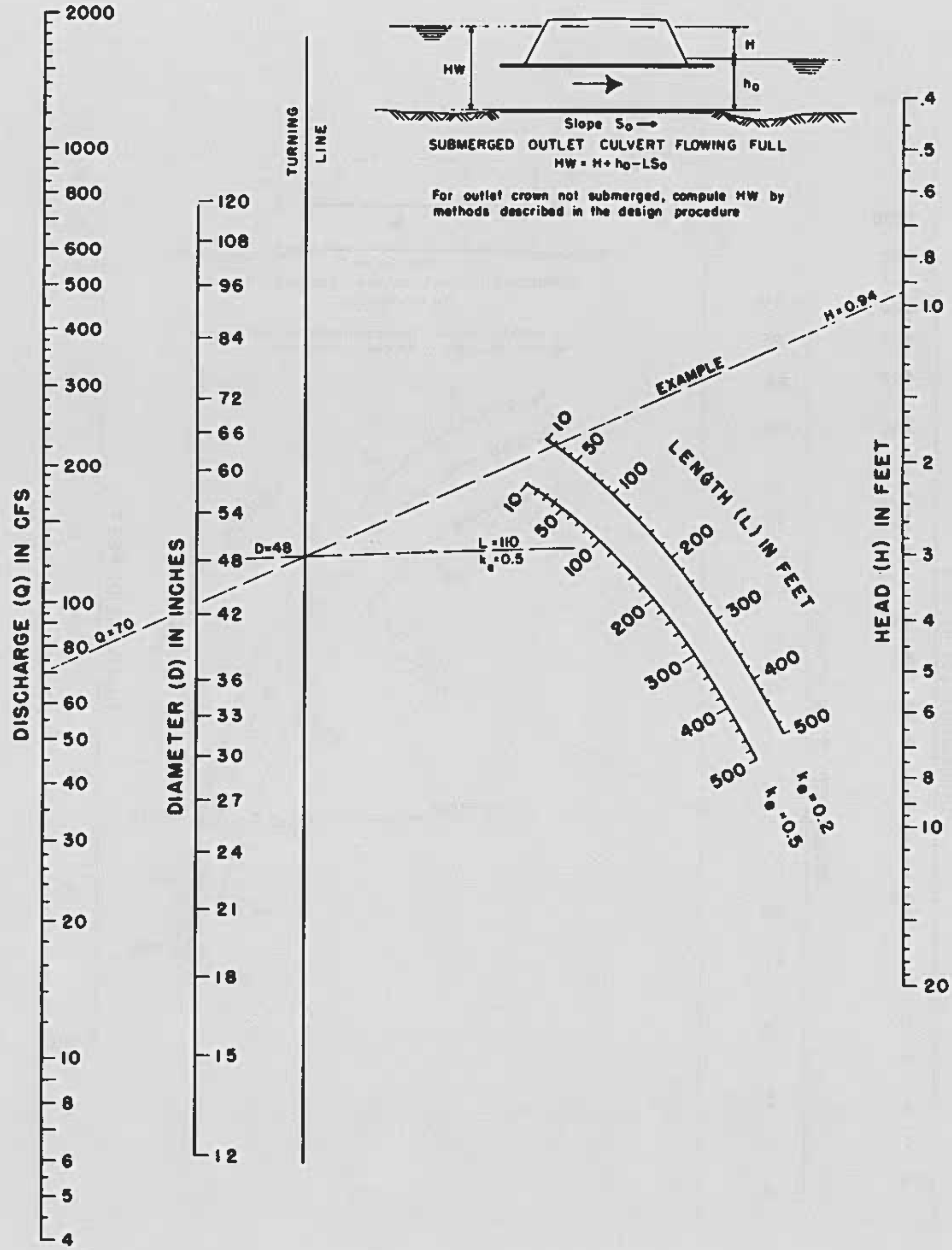


Figure 30 — Head for Concrete Pipe Culverts Flowing Full with Outlet Control n = 0.012 (Ref. Hyd. Eng. Cir. No. 5, USBPR, 1965)

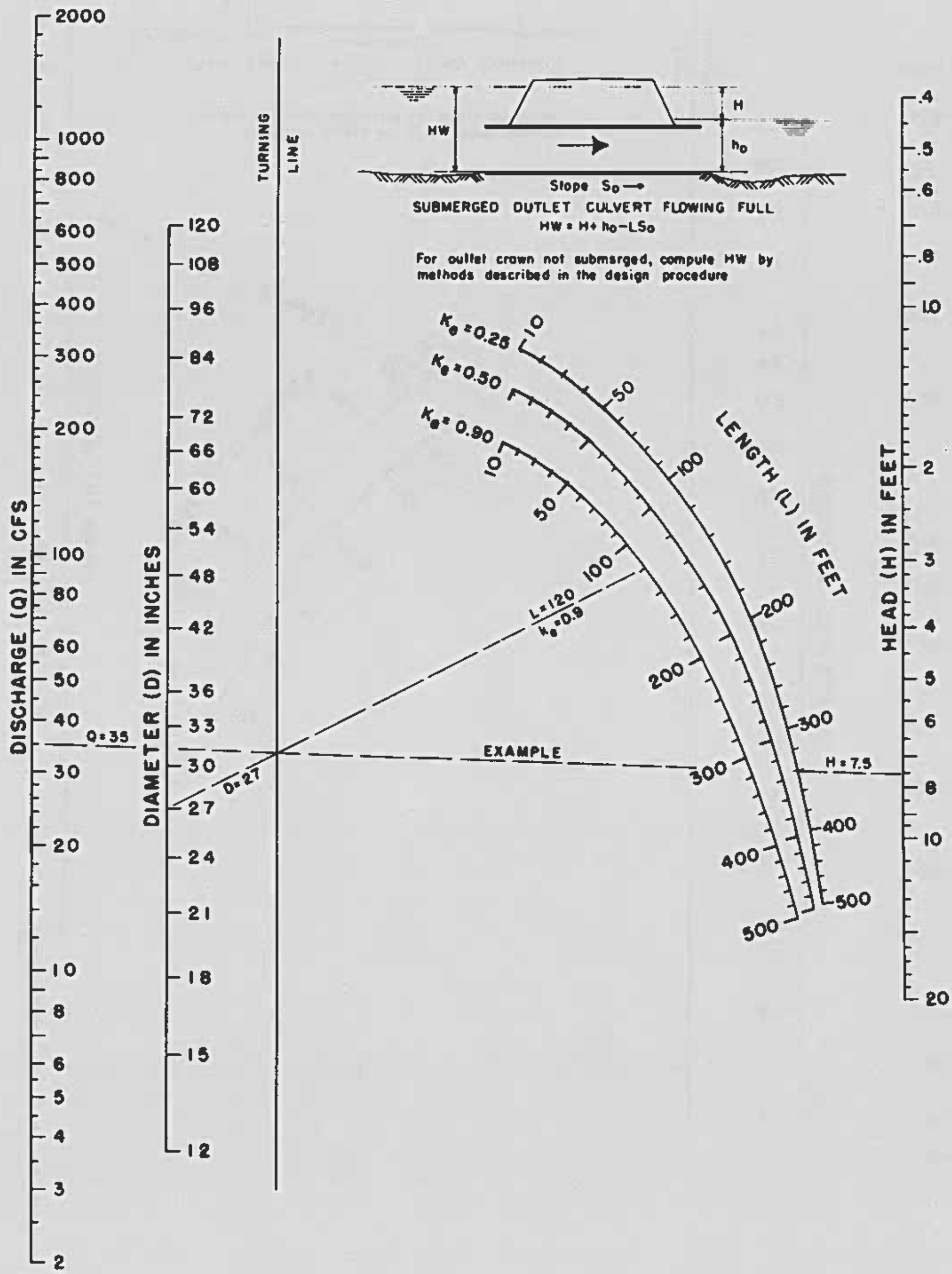


Figure 31 — Head for CM Pipe Culverts Flowing Full with Outlet Control n = 0.024 (Ref. Hyd. Eng. Cir. No. 5, USBPR, 1965)

Figure 32 — Culvert Capacity

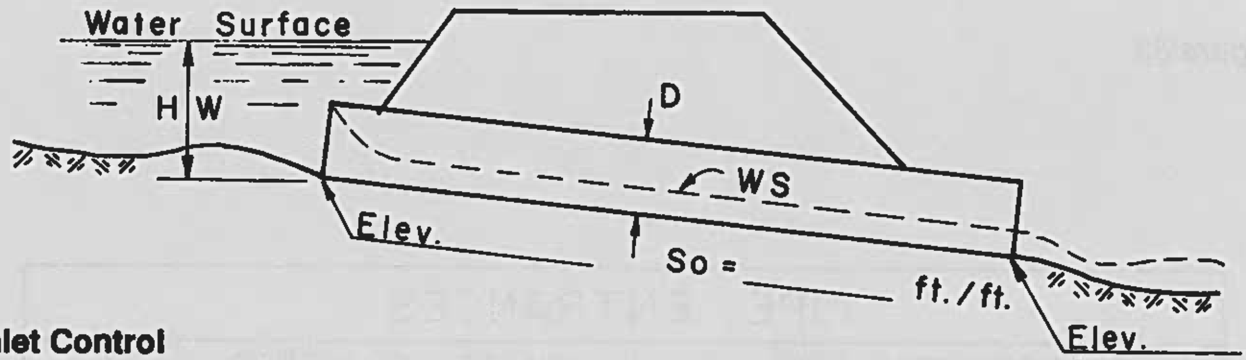
Project ______________________ By __________ Date ________

Location ______________________ Checked By __________ Date ________

Q Required = __________ cfs (Appendix B) Culvert Type __________

Concrete n = 0.012 CMP n = 0.024

Compute Q for both inlet and outlet control, and use the lower value.



Inlet Control

Type of inlet: Head Wall ______; Mitered to Conform to Slope _____; Projecting _____

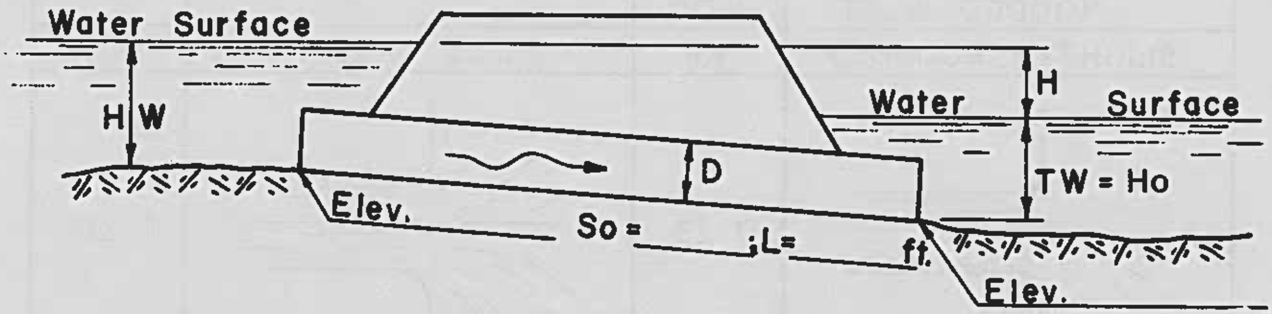
D = ______________ ft.

HW = ______________ ft.

HW/D = ____________ = __________

n = ______________

Q = ______________ cfs (Figure 28 or 29)



Outlet Control

D = ______________ ft.

HW = ______________ ft.

Ho = ______________ ft.

H = HW - Ho + SoL = __________ - __________ + __________ = __________ ft,

(For Free Outlet Ho = 3/4D)

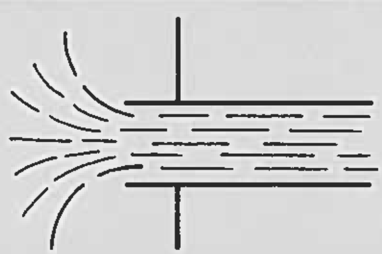
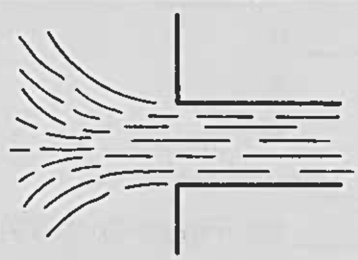
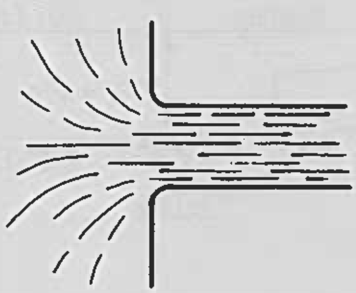
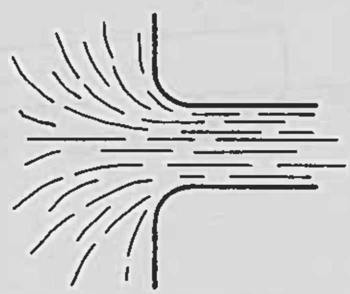
n = ______________

Ke = ____________ (See Figure 33)

Q = ____________ cfs (Figure 30 or 31)

Materials for culvert construction should meet the applicable ASTM standard for the kind of material used. Construction methods should be in accordance with standard procedures of pipe conduits.

Figure 33

PIPE ENTRANCES			
INWARD PROJECTING PIPE	K_e	SHARP - CORNERED	K_e
	0.78		0.50
HOODED INLET	1.00		
SLIGHTLY ROUNDED	K_e	BELL MOUTH	K_e
	0.23		0.20

Section 5
Structural Measures — Temporary

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Temporary Sediment Control Measures

General

These are temporary measures, with a short life expectancy, to control sediment and erosion. They should be used especially around construction sites and new developments. These types of sediment control measures call for considerable maintenance and inspection. Maintenance of removing sediment after every storm is very important, along with replacing damaged materials.

Straw bales installed in a line to retard sediment runoff.

A silt fence will retard runoff until sediment has dropped out.

Straw Bale Dikes

Definition: A "temporary" barrier with a life expectancy of three months or less, installed across or at the toe of a slope of a construction site or new development.

Purpose: The purpose of a straw bale dike is to intercept and detain small amounts of sediment from unprotected areas of limited extent.

Conditions Where Practice Applies: The temporary straw bale dike may be used where:

1. There is no concentration of water in a channel or other drainage-way above the barrier.

2. Erosion would occur in the form of sheet and rill erosion.

3. The length of slope of the contributing drainage area above the dike is less than 200-feet. The slope should be 15-percent or less. If slope is greater than 15-percent, bale dikes should be located on 100-foot spacings down the slope.

Design Criteria

All bales shall be placed on the contour and should be tied with either wire or nylon string if available. These types of ties will not deteriorate rapidly and insure a longer life. If ordinary baler twine is used, the bales should be placed so that the twine is not in contact with the ground.

Specifications

1. Bales shall be placed in a row with ends tightly abutting the adjacent bales.

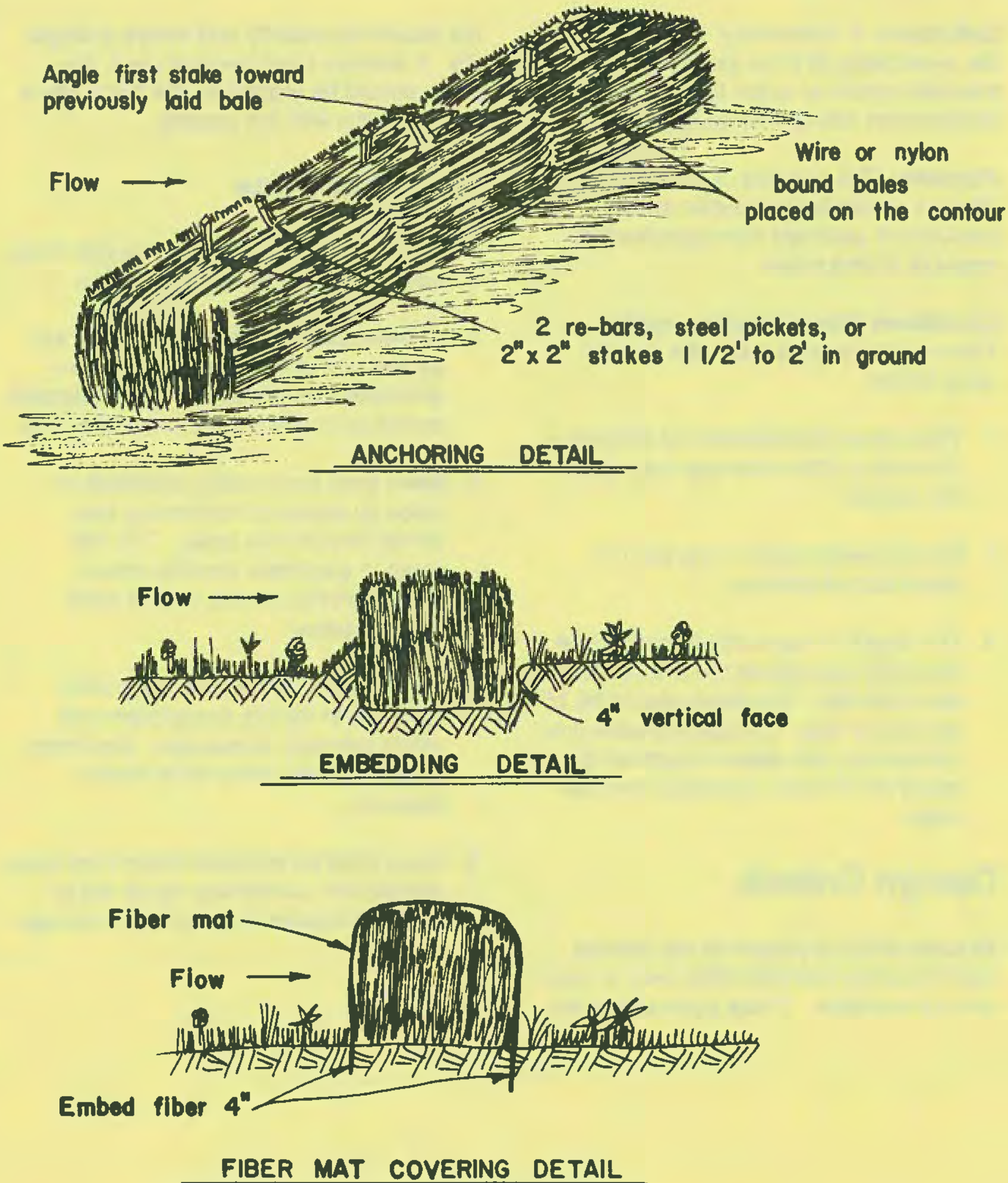
2. All bales shall be embedded in the soil a minimum of 4-inches or bales covered with a fiber mat, with earth tamped on the upstream side to prevent piping.

3. Bales shall be securely anchored in place by stakes or reinforcing bars driven through the bales. The first stake in each bale shall be driven toward previously laid bale to force bales together.

4. An inspection should be made after rainfall and repairs or replacements made promptly as needed. Sediment should also be removed to insure capacity.

5. Bales shall be removed when they have served their usefulness so as not to block or impede storm flow or drainage.

Figure 1 — Straw Bale Dike



Silt Fences

Definition: A temporary barrier with a life expectancy of six months or less, installed below small disturbed areas or at the toe of a slope.

Purpose: The purpose of a silt fence is to intercept and detain sediment from small unprotected areas.

Conditions Where Practice Applies: A silt fence may be used where:

1. There is no concentration of water in a channel or other drainage way above the barrier.

2. Erosion will occur in the form of sheet and rill erosion.

3. Protection of a property line or limits of grading is required.

4. The length of slope of the contributing drainage area above the fence is less than 200 feet. The slope should be 25 percent or less. If slope is greater than 25 percent, fences should be located on 100-foot spacing.

Design Criteria

All silt fences shall be placed as close to the contour as possible.

A detail of the silt fence shall be shown on the plan, and contain the following minimum requirements:

1. The type, size, and spacing of fence posts.

2. The size of woven wire support fence.

3. The type of filter cloth used.

4. The method of anchoring the filter cloth.

Materials

1. Silt Fence Cloth: Filter fabric shall be a pervious sheet of woven geotextile fabric consisting of long chain polymeric filaments or yarns such as polypropylene, polyethylene, polyester, polyamide, or polyvinylidene-chloride. The fabric shall be fixed so that the filaments or yarns retain their relative positions to each other. The fabric shall be resistant to commonly encountered chemicals, mildew, rot, insects, and rodents.

2. Fence Posts: The length shall be minimum of 48 inches long. Wood posts will be of sound quality hardwood with a minimum diameter of 2 inches, or as approved. Steel posts will be standard T or U section weighing not less than 1.33 pounds per linear foot.

3. Wire Fence: Woven wire fencing shall be a minimum 14 1/2 gage with maximum 6-inch mesh openings, or as approved.

Prefabricated Silt Fence: Prefabricated silt fence with posts attached is available. This fence is installed in a manner similar to that described above. While this type of fence is cheaper and easier to install, it requires more maintenance in order to perform satisfactorily.

Specifications

1. The fence posts shall be spaced a maximum distance of 10 feet center-to-center.

2. Woven wire fence shall be fastened securely to the upstream side of the fence posts by staples or wire ties.

3. Staple or fasten securely the filter cloth to the upstream side of the woven wire. Allow sufficient filter cloth for anchor at the bottom.

4. The filter cloth shall be embedded in the soil a minimum of 4 inches, and have compact soil to hold it in place.

5. The inspection shall be frequent and the filter cloth shall be replaced promptly as needed if it is torn. Sediment should also be removed to insure capacity.

Figure 2 — Silt Fence Detail

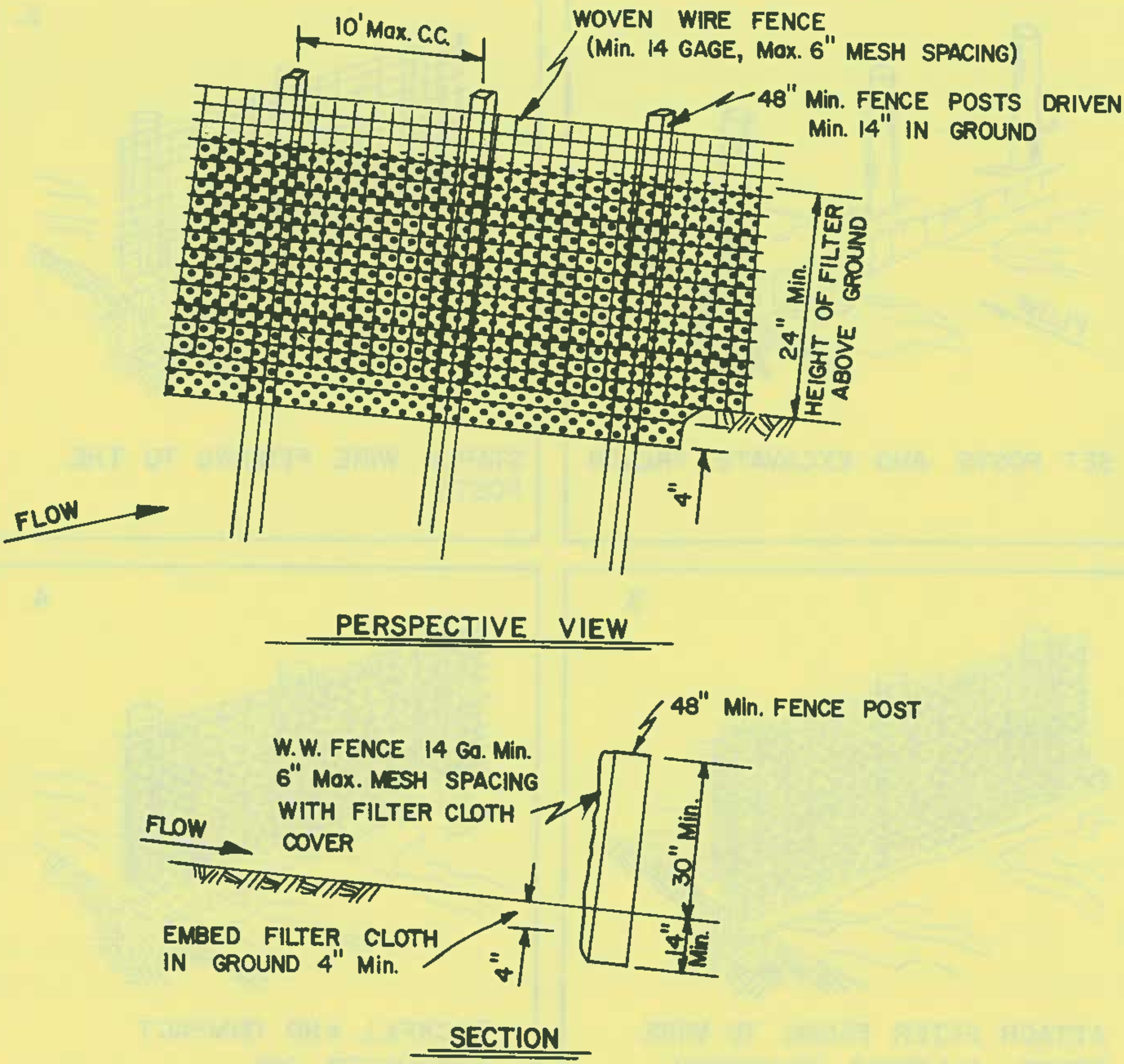
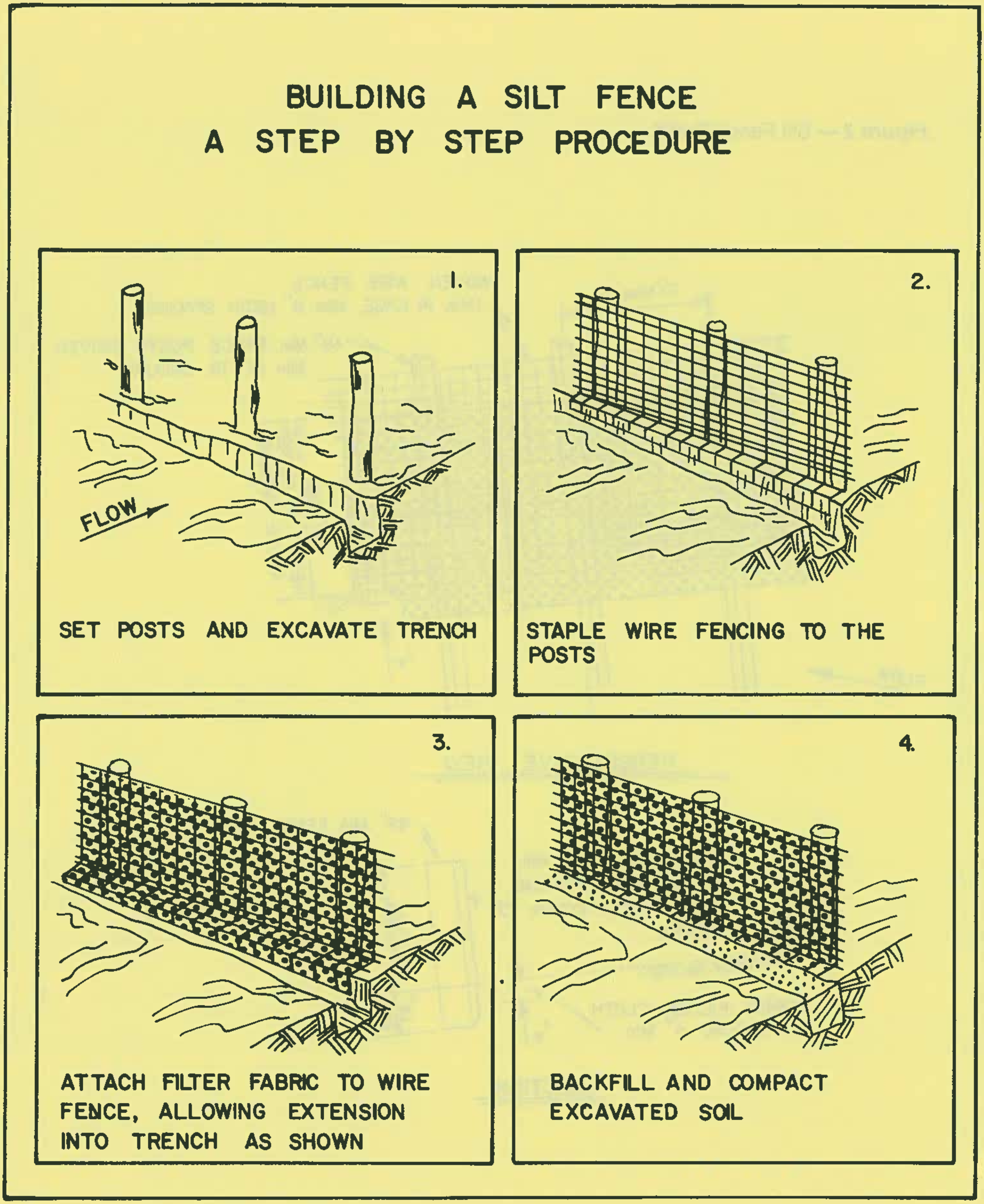


Figure 3


BUILDING A SILT FENCE
A STEP BY STEP PROCEDURE
1.
FLOW
SET POSTS AND EXCAVATE TRENCH
2.
STAPLE WIRE FENCING TO THE POSTS
3.
ATTACH FILTER FABRIC TO WIRE FENCE, ALLOWING EXTENSION INTO TRENCH AS SHOWN
4.
BACKFILL AND COMPACT EXCAVATED SOIL

Check Dams

Definition: Small temporary dams constructed across a swale or drainage ditch.

Purpose: To reduce the velocity of concentrated storm water flows, thereby reducing erosion of the swale or ditch. This practice also traps small amounts of sediment generated in the ditch itself. However, this is not a sediment trapping practice and should not be used as such.

Conditions Where Practice Applies: This practice is limited to use in small open channels which drain 30 acres or less. It should not be used in a live stream. Some specific applications include:

1. Temporary ditches or swales which, because of their short length of service, cannot receive a non-erodible lining but still need some protection to reduce erosion.

2. Permanent ditches or swales which for some reason cannot receive a permanent non-erodible lining for an extended period of time.

3. Either temporary or permanent ditches or swales which need protection during the establishment of grass linings.

Planning Considerations

Check dams can be constructed of either stone or logs.

If stone check dams are used in grass-lined channels which will be mowed, care should be taken to remove all the stone from the dam when the dam is removed. This should include any stone which has washed downstream.

Since log check dams are embedded in the soil, their removal will result in more disturbance of the soil than will removal of stone check dams. Consequently, extra care should be taken to stabilize the area when log dams are used in permanent ditches or swales.

Design Criteria

No formal design is required for a check dam; however, the following criteria should be adhered to when using check dams.

The drainage area of the ditch or swale being protected should not exceed 30-acres. The maximum height of the check dam should be 4-feet. The center of the check dam must be at least 6-inches lower then the outer edges. The maximum spacing between the dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam. The side slopes of stone dams should not be steeper than 2:1.

Stone check dams should be constructed of ASTM D448 No. 2 or 3 (2- to 3-inch stone). Hand or mechanical placement will be necessary to achieve complete coverage of the ditch or swale and to insure that the center of the dam is lower than the edges.

Log check dams should be constructed of 4- to 6-inch logs salvaged from clearing operations on site, if possible. The logs should be embedded into the soil at least 18-inches. The 6-inch lower height required at the center can be achieved either by careful placement of the logs or by cutting the logs after they are in place. Logs should be placed as an apron on the downstream side of the dam to prevent scour during high flows.

Sediment Removal: While this practice is not intended to be used primarily for sediment trapping, some sediment will accumulate behind the check dams. Sediment should be removed from behind the check dams when it has accumulated to one half of the original height of the dam.

Removal: Check dams must be removed when their useful life has been completed. In temporary ditches and swales, check dams should be removed and the ditch filled in when it is no longer needed. In permanent structures, check dams should be removed when a permanent lining can be installed. In the case of grass-lined ditches, check dams should be removed when the grass has matured sufficiently to protect the ditch or swale. The area beneath the check dams should be seeded and mulched immediately after they are removed.

Maintenance

Check dams should be checked for sediment accumulation after each significant rainfall. Sediment should be removed when it reaches one half of the original height or before.

Regular inspections should be made to insure that the center of the dam is lower than the edges. Erosion caused by high flows around the edges of the dam should be corrected immediately.

Temporary Stream Crossing

Definition: A temporary structural span installed across a flowing watercourse for use by construction traffic. Structures may include bridges, round pipes or pipe arches.

Purpose:

1. To provide a means for construction traffic to cross flowing streams without damaging the channel or banks.

2. To keep sediment generated by construction traffic out of the stream.

Conditions Where Practice Applies: Generally applicable to flowing streams with drainage areas less than 1 square mile. Structures which must handle flow from larger drainage areas should be designed as permanent structures by a registered professional engineer.

Planning Considerations

Temporary stream crossings are necessary to prevent construction vehicles from damaging streambanks and continually tracking sediment and other pollutants into the stream. However, these structures are also undesirable in that they represent a channel constriction which can cause flow backups or washouts during periods of high flow. For this reason, the temporary nature of stream crossings is stressed. They should be planned to be in service for the shortest practical period of time and to be removed as soon as their function is completed.

The specifications contained in this practice pertain primarily to flow capacity and resistance to washout of the structure.

From a safety and utility standpoint, the designer must also be sure that the span is capable of withstanding the expected loads from heavy construction equipment which will cross the structure.

Design Criteria

1. The structure shall be large enough to convey the flow expected from a 2-year frequency storm without appreciably altering the stream flow characteristics. The structure may be a span or culvert. If culverts are selected, the standard on culverts may be used to determine the appropriate size. Multiple culverts may be used in place of one large culvert if they have the equivalent capacity of the larger one. The minimum-sized culvert that may be used is 18-inches.

2. Where culverts are installed, compacted soil or rock will be used to form the crossing. The depth of cover over the culvert shall be a minimum of 12 inches. To protect the sides of soil fill from erosion, riprap shall be used and be designed in accordance with the standard for open channels.

3. The length of the culvert shall be adequate to extend the full width of the crossing, including side slopes.

4. The slope of the culvert shall be at least 0.25 inch-per foot.

5. The top of the compacted fill and approaches shall be covered with 6 inches of crushed stone.

Operation and Maintenance

An operation and maintenance plan will be developed for the crossing. The plan shall include, as a minimum, the following items:

1. Inspection of the crossing periodically and after each large storm event for accumulation of debris or damage to the structure.

2. Repair of eroding areas and replacement of surfacing materials if washed away.

3. Removal of sediment and/or debris accumulations on or around the crossing or access.

Specifications

The crossing will be installed at the location and in the manner shown on the drawings.

Construction shall be done in such a way that chemicals, fuels, lubricants, and waste materials will not enter the flow area. Erosion, air pollution, and water pollution will be minimized and held within legal limits.

Measures and construction methods that enhance fish and wildlife values and those for erosion and sediment control shall be incorporated as shown on the drawings. In addition, the following methods or practices will be utilized to the degree possible in the construction of the crossing, to reduce the potential for sedimentation of the stream:

1. Divert the stream flow to one side of the channel while construction is done on the opposite side. Or, where possible, temporarily dam the channel and pipe or pump the stream flow past the construction area.

2. Perform construction activities from the bank as much as possible. Use backhoes or excavators instead of dozers and use rubber tired equipment when construction activity must be conducted in the water.

3. Build the crossing when high flows are not expected.

4. Haul all excavated material to the appropriate disposal area, grade, and seed and mulch the material as soon as possible.

When required, all trees, shrubs, brush, and debris within the construction limits will be cleared and grubbed to a depth that will permit installation of the crossing. All materials will be burned, buried, or piled in designated disposal areas. The clearing operation will be conducted in a manner to avoid damage to vegetation or property outside the work area and to prevent disturbance within the stream. Special attention will be given to protecting and maintaining key shade, food, and den trees when their removal is not necessary.

Excavation of the crossing will be completed to the line and grade shown on the drawings. All excavated material will be removed from the limits of the channel and hauled to designated waste disposal areas. The excavated material may be utilized to shape the entrance areas to the crossing to provide free drainage and stability to the areas.

Rock riprap shall be limestone or sandstone and will be well graded within the limits shown on the drawings. It will be dense, sound, and free from, cracks, seams, and other defects conducive to accelerated weathering. The rock fragments shall be angular to subrounded in shape.

The riprap shall be placed to the required thickness in one operation. The rock will be delivered and placed in a manner that will insure the riprap in place will be reasonably homogeneous with the larger rocks uniformly distributed and firmly in contact one to another with the smaller rocks filling the voids between the larger rocks.

Surfacing material will be hard, durable limestone or sandstone aggregates meeting the grading limits shown on the drawings. It will be placed to the required thickness in one operation and in such a manner that segregation of the particle sizes will not occur. After placement the aggregate will be consolidated by traversing the entire surface of the crossing with four passes of the construction equipment.

Upon completion of construction, all disturbed areas shall be graded smooth and blend with the surrounding ground.

A protective cover of vegetation shall be established on all exposed surfaces where soil and climatic conditions permit. Lime and fertilizer shall be spread at the specified rate and disked into soil to a depth of 4 inches to prepare a seedbed. Seed and mulch shall be applied at the specified rate. Mulch along the streambank will be anchored by mulch netting. Excelsior erosion control blankets may be used in lieu of the mulch and netting. Mulch netting or excelsior blankets will be held in place with 6-inch wire staples placed 3-feet on centers in all directions.

In some cases, temporary vegetation may be used for protection until conditions are suitable for establishment of permanent vegetation. Where soil or climatic conditions do not permit the establishment of vegetation, and protection is needed, nonvegetative means such as mulches or gravel may be used.

The crossing shall be removed as soon as it is no longer necessary for project construction. Upon removal of the structure, the stream shall be reshaped to its original cross-section and properly stabilized.

Construction Road Stabilization

Definition: The temporary stabilization of access roads, subdivision roads, parking areas, and other on-site vehicle transportation routes with stone immediately after grading.

Purposes:

1. To reduce the erosion of temporary roadbeds by construction traffic during wet weather.

2. To reduce the erosion and therefore regrading of permanent roadbeds between the time of initial grading and final stabilization.

Conditions Where Practice Applies: Wherever stone-base roads or parking areas are constructed, whether permanent or temporary, for use by construction traffic.

Planning Considerations

Areas which are graded for construction vehicle transport and parking purposes are especially susceptible to erosion. The exposed soil surface is continually disturbed, leaving no opportunity for vegetative stabilization. Such areas also tend to collect and transport runoff waters along their surfaces. During wet weather, they often become muddy quagmires which generate significant quantities of sediment that may pollute nearby streams or be transported off site on the wheels of construction vehicles. Dirt roads can become so unstable during wet weather that they are virtually unusable.

Permanent roads and parking areas should be paved as soon as possible after grading. As an alternative, the early application of stone may solve potential erosion and stability problems and eliminate later regrading costs. Some of the stone will also probably remain in place for use as part of the final base course of the road.

Design Criteria

1. Temporary roads shall follow the contour of the natural terrain to the extent possible. Slopes should not exceed 10 percent.

2. Temporary parking areas should be located on naturally flat areas to minimize grading. Grades should be sufficient to provide drainage but should not exceed 4-percent.

3. Roadbeds shall be at least 14 feet wide for one-way traffic and 20-feet wide for two-way traffic.

4. All cuts and fills shall be 2:1 or flatter to the extent possible.

5. Drainage ditches shall be provided as needed and shall be designed and constructed to prevent erosion of the road surface.

6. The roadbed or parking surface shall be cleared of all vegetation, roots, and other objectionable material.

7. A 6-inch course of crushed aggregate shall be applied immediately after grading or the completion of utility installation within the right-of-way. Filter fabric may be applied to the roadbed for additional stability in accordance with fabric manufacturer's specifications.

8. Permanent roads and parking areas shall be designed and constructed in accordance with applicable West Virginia Department of Highways or local criteria.

9. All roadside ditches, cuts, fills, and disturbed areas adjacent to parking areas and roads shall be stabilized with appropriate temporary or permanent vegetation according to the applicable standards and specifications contained in this handbook.

Maintenance

Both temporary and permanent roads and parking areas may require periodic top dressing with new gravel. Seeded areas adjacent to the roads and parking areas should be checked periodically to insure that a vigorous stand of vegetation is maintained. Roadside ditches and other drainage structures should be checked regularly to insure that they do not become clogged with silt or other debris.

Temporary Construction Entrance

Definition: A stone stabilized pad located at points of vehicular ingress and egress on a construction site.

Purpose: To reduce the amount of mud transported onto public roads by motor vehicles or runoff.

Conditions Where Practice Applies: Wherever traffic will be leaving a construction site and move directly onto a public road or other paved area.

Planning Considerations

Construction entrances provide an area where mud can be removed from construction vehicle tires before they enter a public road. If the action of vehicle traveling over the gravel pad is not sufficient to remove the majority of the mud, then the tires should be washed before the vehicle enters a public road. If washing is used, provisions must be made to intercept the wash water and trap the sediment before it is carried off-site. Construction entrances should be used in conjunction with the stabilization of construction roads to reduce the amount of mud picked up by construction vehicles.

Design Criteria

1. ASTM D448 No. 2 or 3 or equivalent (2-3-inch stone) should be used.
2. The aggregate layer should be at least 6 inches thick. It must extend the full width of the vehicular ingress and egress area. The length of the entrance should be at least 50 feet.
3. If conditions on the site are such that the majority of the mud is not removed by the vehicles traveling over the gravel, then the tires of the vehicles should be washed before entering a public road. Wash water must be carried away from the entrance to a settling area to remove sediment. A wash rack may also be used to make washing more convenient and effective.
4. The entrance should be located to provide for maximum utility by all construction vehicles.
5. Filter fabric may be placed beneath the aggregate for additional stability in accordance with the fabric manufacturer's specifications.

Maintenance

The entrance shall be maintained in a condition which will prevent tracking or flow of mud onto public rights-of-way. This may require periodic top dressing with 2-inch stone, as conditions demand, and repair and/or cleanout of any structures used to trap sediment. All materials spilled, dropped, washed, or tracked from vehicles onto roadways or into storm drains should be removed immediately.

Specifications

The area of the entrance should be cleared of all vegetation, roots, and other objectionable material. The gravel shall be placed to the specified dimensions. Any drainage facilities required because of washing should be constructed according to specifications. If wash racks are used, they should be installed according to manufacturer's specifications.

Dust Control

Definition: Reducing surface and air movement of dust during construction activities.

Purpose: To prevent surface and air movement of dust from exposed soil surfaces and reduce the presence of airborne substances which may be harmful or injurious to human health, welfare, or safety, or to animal or plant life.

Conditions Where Practice Applies: In areas subject to surface and air movement of dust where on-site and off-site damage is likely to occur if preventive measures are not taken.

Planning Considerations

Construction activities inevitably result in the exposure and disturbance of soil. Dust is emitted both during the activities (i.e., excavation, demolition, vehicle traffic, human activity) and as a result of wind erosion over the exposed earth surfaces. Large quantities of dust are typically generated in "heavy" construction activities, such as road and street construction and subdivision, commercial or industrial development, which involve disturbance of significant areas of soil surface. Earth-moving activities comprise the major source of construction dust emissions, but traffic and general disturbance of the soil also generate significant dust emissions.

In planning for dust control the amount of soil exposed at any one time should be kept to an absolute minimum. Therefore, phasing a project and utilizing temporary stabilization practices upon the completion of grading can significantly reduce dust emissions.

Temporary Measures

1. ***Mulches*** — See *Mulching.*

2. ***Vegetative Cover*** — See *Temporary Critical Area Planting.*

3. ***Irrigation*** — This is generally done as an emergency treatment. Site is sprinkled with water until the surface is wet. Repeat as needed.

   To prevent carryout of mud onto streets, refer to *Temporary Construction Entrance.*

4. ***Barriers*** — Solid board fences, snow fences, burlap fences, crate walls, bales of hay and similar material can be used to control air currents and soil blowing. Barriers placed at right angles to prevailing currents at intervals of about 15-times the barrier height are effective in controlling wind erosion.

5. ***Calcium Chloride*** — Apply at rate that will keep surface moist. May need retreatment.

Permanent Measures

1. ***Permanent Vegetation*** — See standards for *Permanent Critical Area Planting.* Existing trees and large shrubs may afford valuable protection if left in place.

2. ***Topsoiling*** — This entails covering the surface with less erosive soil material. See *Topsoiling.*

3. ***Stone*** — Cover surface with crushed stone or coarse gravel.

Section 6
Appendices

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Appendix A
Glossary

The list of terms that follows is representative of those used by soil conservationists, soil scientists, engineers, developers, contractors, planners, and others involved in developing areas.

AASHTO — American Association of State Highway and Transportation Officials.

Acidity, Soil — The degree of acidity or alkalinity of a soil expressed in pH values. A soil that tests pH 7.0 is precisely neutral in reaction. Numbers lower than that indicate increasing acidity.

Acre-foot — The volume of water that will cover one acre to a depth of one foot. An acre-foot contains 43,560 cubic feet or 325,829 gallons.

Aesthetics — An approach dealing with the beautiful and with judgments concerning beauty.

Annual — A plant that completes its life cycle in one year or less.

Anti-seep Collar — A sheet of material that extends a minimum of 2 feet around a pipe, culvert or spillway to deter water seepage along the tube. This collar can be made of such material as concrete, steel, and plastic.

Apron — A floor or lining to protect a surface from erosion; for example, the pavement below chutes, spillways, or at the toes of dams.

Aquifer — A geologic formation or structure that transmits water underground. The term "water-bearing" is sometimes used synonymously with stratum to mean the same thing, and such water may be used for specific, planned purposes. Aquifers are usually saturated sands, gravel, fractures, caverns, or vesicular rock.

Asphalt Emulsion — An emulsifiable asphalt diluted 1:1 with water and used to tack or stick mulch together to help hold it in place.

Base Flow — The stream discharge from groundwater runoff. See *Runoff.*

Bedding — The process of laying a drain or other closed conduit in its trench and tamping earth or pouring concrete around the conduit to form its bed. The manner of bedding should be specified to conform to the earth load and conduit strength.

Bedload — The sediment that moves by sliding, rolling, or bounding on or very near the streambed. This is sediment moved mainly by tractive or gravitational forces or both but at slower speeds than the surrounding flow.

Bedrock — The solid rock that underlies the soil and other unconsolidated material. It also may be exposed at the surface.

Berm — A shelf that breaks the continuity of a slope.

Blind Drain — A type of drain consisting of an excavated trench refilled with pervious materials such as coarse sand, gravel, or crushed stones, through whose voids water percolates and flows toward an outlet. This is often referred to as a French drain because of its origin and widespread use in France.

Blind Inlet — Inlet to a drain in which entrance of water is by percolation rather than open flow channels.

Channel — A natural stream that conveys water; a ditch or channel excavated for the flow of water.

Channel Stabilization — Erosion prevention by stabilizing velocity distribution in a channel, using such measures as jetties, drops, revetments, and vegetation.

Chute — A high-velocity, open channel for conveying water to a lower level without erosion, and may be constructed from such material as vegetative soil, concrete, or steel.

Clay — As a soil separate, the mineral soil particles less than 0.002 of a millimeter in diameter.

Claypan — A compact, slowly permeable soil horizon that contains more clay than the horizon above and the one below it. A claypan is commonly hard when dry and plastic when wet.

CMP - Corrugated metal pipe.

Coefficient of Roughness (Hydraulics) — A factor in velocity and discharge formulas representing the effect of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.

Compaction — The process by which the soil grains are rearranged to decrease void space and bring them into closer contact with one another by rolling and tamping, thereby increasing the weight of solid material per cubic foot.

Conduit — Any channel intended for the conveyance of water, whether open or closed.

Contamination — A state of being polluted or impure, used here to indicate chemical, sediment, or bacteriological impurities in water.

Contour — An imaginary line on the land connecting points of the same elevation; a line drawn on a map to show the location of points of the same elevation; a series of such contours serving to delineate the topography of the land.

Crib Dam — A barrier of timber, forming bays or cells that are filled with stone or other heavy material.

CSM - Cubic feet per second per square mile of drainage area.

Cubic Feet Per Second — Rate at which the cubic footage of fluid passes a measuring point in one second. Abbreviation: cfs. Synonyms: Second-foot; CUSEC.

Cultipacker — A heavy, corrugated roller used to firm soil during seedbed preparation.

Cutoff — 1. Wall, collar, or other structure, such as a trench, filled with relatively impervious material intended to reduce seepage of water through otherwise porous strata. 2. In river hydraulics, the new and shorter channel formed either naturally or artificially when a stream cuts through the neck of a bend.

Dam — A barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent gully erosion, or for retention of soil, rock, sediment, or other debris.

Debris — A term applied to the loose material arising from the disintegration of rocks and vegetative material, transportable by streams, ice, or floods.

Dike — An embankment to confine or control water, especially one built along the banks of a river to prevent overflow of lowlands.

Discharge (Hydraulics) — Rate of flow, specifically fluid flow; a volume of fluid passing a point per unit time, commonly expressed as cubic feet per second, million gallons per day, gallons per minute, or cubic meters per second.

Diversion — A channel with or without a supporting ridge on the lower side, constructed across or at the bottom of a slope for the purpose of diverting water flow.

Dominance — The influence or control over ecological communities exerted by a dominant.

Drainage — 1. The removal of excess surface water or groundwater from land by means of surface and/or subsurface drains. 2. Soil characteristics that affect natural drainage.

Drop-inlet Spillway — Overfall structure in which the water drops through a vertical rise connected to a discharge conduit.

Drop Structure — A structure for dropping water to a lower level and dissipating its surplus energy. A drop may be vertical or inclined.

Earth Dam — Dam constructed of compacted soil materials.

Emergency Spillway — A spillway used to carry runoff exceeding a given design flood. The spillway itself will then carry a design storm.

Erosion — The wearing away of the land surface by action of wind, water, or ice.

Flood Plain — Nearly level land, consisting of stream sediments, that borders a stream and is subject to flooding unless protected artificially.

Fragipan — A dense, brittle horizon that is very low in organic matter and clay but rich in silt or very fine sand. The layer is seemingly cemented when dry and has hard or very hard consistency.

Freeboard (Hydraulics) — Vertical distance between the maximum water surface elevation anticipated in design and the top of retaining banks or structures provided to prevent overtopping because of unforeseen conditions.

Gabion — A galvanized-wire basket filled with stone used for structural purposes. When fastened together, they are used as retaining walls and revetments, for slope protection, and similar structures.

Grade — 1. The slope of a road, channel, or natural ground. 2. The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared for the support of construction, such as paving or laying conduit. 3. To finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation.

Grade Stabilization Structure — A structure for the purpose of stabilizing the grade of a gully or other watercourse; thereby preventing further headcutting or lowering of the channel grade.

Grassed Waterway — A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses, used to conduct occasional surface water.

Gravel Filter — Graded sand and gravel aggregate placed around a drain to inhibit the movement of fine materials from the aquifer into the drain.

Gully — A miniature valley with steep sides cut by running water, and through which water ordinarily runs only after rains. A gully is of sufficient depth that it would not be obliterated by normal tillage operations. A rill is of lesser depth and would be smoothed by ordinary tillage.

Herbaceous Plant — A plant that remains succulent and does not develop woody tissue.

Herbicide — A chemical for killing plants.

Hood Inlet — Entrance to a closed conduit that has been shaped to induce full flow at minimum water surface elevation.

Hydraulic Grade Line — In a closed conduit, a line joining the elevations to which water could stand in risers or vertical pipes connected to the conduit at their lower end and open at their upper end. In open channel flow, the hydraulic grade line is the freewater surface.

Hydraulic Radius — The cross-sectional area of a stream divided by its wetted perimeter. This is represented by the "r" in Manning's formula.

Hydroseeder — A machine that mixes water and various combination of seed, fertilizer, ground limestone and mulch in a tank to form a slurry. The material is sprayed under high pressure over the area to be seeded.

Infiltration Rate — A soil characteristic describing the maximum rate at which water can enter the soil under specified conditions.

Jute Netting — A coarse, open mesh, web-like material woven of heavy (strands of 1/4-inch diameter or larger) jute twine. It serves the purpose of mulch and has the tensile strength and weight to resist water flow and erosion.

Landscape Planning — The art and science of analyzing, planning, and designing the physical landscape for beneficial human use and the conservation of the natural landscape resource.

Deterioration of the Landscape — Occurring when new elements are introduced and the effects are inadequately reclaimed due to little or no visual resource planning.

Destruction of the Landscape — Occurring when the introduction of elements causes abrupt changes and rapid damage due to no regard for visual resource planning.

Preservation of the Landscape — Occurring when existing elements of the landscape are incorporated into the proposed project with minimal disturbance.

Enhancement of the Landscape — Occurring v hen visual quality is improved upon by the project, with proper visual resource planning.

Modification of the Landscape — Occurring when created visual components are unnaturally strong compared to the adjacent landscape. Treatment is needed to create elements that compliment one another.

Land Leveling — The process of shaping the land surface for better movement of water and machinery over the land. This is also called land forming, land shaping, or land grading.

Landslide — The downward sliding or falling of either a dry or wet mass of earth, rock, or a mixture of the two. The slope is usually steep. Movement may be slow to rapid. Water is usually present helping to lubricate the mass, but true landslides do not contain enough liquid to cause the mass to flow.

Manning's Formula (Hydraulics) — A formula used to predict the velocity of water flow in an open channel or pipeline:

$$V = \frac{1.49\, r^{2/3} S^{1/2}}{n}$$

V is the mean velocity of flow in feet per second; r is the hydraulic radius; s is the slope of the energy gradient or for assumed uniform flow the slope of the channel in feet per foot; and n is the roughness coefficient or retardant factor of the channel lining.

Mottled — Irregularly marked with spots of different colors that vary in number and size. Mottling in soils may indicate poor aeration and lack of drainage.

Mulch — Vegetable or synthetic material strewn on the ground to protect it from heat, to conserve moisture, and to reduce soil damage from wind or water. It may also be composed of an incoherent arrangement of aggregates.

Mulch Netting — Man-made material used to anchor mulch to prevent movement of the mulch by wind, water, or other forces.

Outlet — Point of water disposal from a stream, river, lake, tidewater, or artificial drain.

Parent Material (Soil) — The horizon of weathered rock or partly weathered soil material from which soil has formed.

Perennial — A plant that persists for several years.

Pesticide — An agent to destroy pests such as insects or rodents.

Principal Spillway — An open or closed channel constructed of permanent material used to convey excess water from a reservoir and designed to provide flood protection or to reduce the frequency of operation of the emergency spillway.

Pure Live Seed — % purity X % germination = % pure live seed. An excellent method to compare seed lots and upon which to base planting rates.

Rainfall — A fall of rain; the amount of water that falls as rain, expressed in inches of depth.

Reaction (Soil) — The degree of acidity or alkalinity of a soil expressed in pH values. A soil that tests pH 7.0 is precisely neutral in reaction, neither acid nor alkaline.

Relief — The elevations or inequalities of a land surface, considered collectively.

Rill — A steep-sided channel resulting from accelerated erosion. A rill normally is a few inches in depth and width. A rill may later become a gully or may be left the size it is due to more rapid erosion along other drainage ways.

Retardance (Vegetation) — The characteristics of the vegetative lining of a channel that tends to restrict and impede flow relative to a perfectly smooth channel.

Riprap — Broken rock, cobbles, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves or flow).

Runoff (Hydraulics) — That portion of the precipitation on a drainage area that is discharged from the area in stream channels. Types include surface runoff, groundwater runoff, and seepage.

Sand — Individual rock or mineral fragments in soils having diameters ranging from 0.05 of a millimeter to 2.0 millimeters.

Sediment — Solid material being carried or deposited by water, wind, gravity, or ice.

Sediment Dam — A barrier built across a stream channel to retain rock, sand, gravel, silt, or other material.

Sheet Erosion — Gradual and uniform removal of soil material from the surface of the soil, without formation of rills and gullies.

Side Slopes (Engineering) — The slope of the sides of a canal, dam, or embankment. It is customary to name the horizontal rating first, such as 1.5 to 1, or frequently, 1-1/2:1, meaning a horizontal distance of 1.5-feet for every 1-foot vertical.

Silt — Individual mineral particles in a soil that range in diameter from the upper limit of clay (0.002 of millimeter) to the lower limit of very fine sand (0.05 of a millimeter).

Slip — See *Landslide*.

Specifications — A written description or a detailed precise presentation of something or of a plan or proposal for something.

Spillway — An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.

Spoil — Soil or rock material excavated from a canal, ditch, basin, or similar construction.

Standard — Something established by proven ability or longevity, by authority, custom, or general consent as an example or approved practice.

Subsoil — Technically, the B horizon. Commonly, it is that part of the profile below 8 inches in a soil profile.

Surface Soil — The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, and about 5 to 8 inches in thickness. It is the plow depth layer.

Topsoil — Specifically, the top or surface portion of the soil, or the A horizon; high in organic matter and usually the most favorable part of the soil profile for plant growth.

Topsoiling — Obtaining topsoil (or soil material favorable to plant growth) from other places and placing it over an area where vegetation is to be established.

Toxic — Poisonous, injurious to plants through contact or systemic action. Toxicity is present in the surface of acid-producing material and/or soils of high mineral content and severely limits establishment and growth of vegetation.

Water Table — The highest part of the soil or underlying rock material that is wholly saturated with water.

Waterway — A natural course or constructed channel for the flow of water

Winter Annual — An annual plant that starts germination in the fall, lives over winter, and completes its growth the following season.

Appendix B
Estimating Runoff

Introduction

The increased amount of erosion occurring with the conversion of rural land to urban areas depends on the amount of runoff that occurs as well as the amount of disturbance to natural vegetation and land forms. This section addresses what influences runoff and how the volume and rate of runoff is determined. The method and most of the material is reprinted from Urban Hydrology for Small Watersheds, TR—55, Soil Conservation Service, June 1986. The user is urged to obtain a copy of TR—55 and become familiar with the concepts and methods which it contains.

Factors Affecting Runoff

Rainfall: Precipitation, whether it occurs as rain or snow, is the potential source of water that may run off the surface of small watersheds. The extent of the storm and the distribution of rainfall during the storm are two major factors which affect the peak rate of runoff.

The storm distribution can be thought of as a measure of how the rate of rainfall (intensity) varies within a given time interval. For example, in a given 24—hour period, a certain amount of precipitation may have been measured, However, this precipitation may have occurred over the entire 24—hour period or in just one hour. These two situations represent two entirely different storm distributions.

The size of the storm is often described by the length of time over which precipitation occurs, the total amount of precipitation occurring and how often this same storm might be expected to occur (frequency). Thus a 10—year, 24—hour storm can be thought of as a storm producing the amount of rain in 24 hours with a 10% chance of occurrence in a year. One day (24 hour) rainfall tables are listed as Exhibit B—1 at the end of this section for 1, 2, 5, 10, 25, 50 and 100—year frequencies.

Antecedent Moisture Condition: The runoff from a given storm is affected by the existing soil moisture content resulting from the amount of precipitation occurring during the preceding five days (antecedent moisture condition).

Watershed Area: The watershed area or area draining water to the point of interest is usually determined from a topographic map or scaled aerial photograph accompanied by a field review locating manmade features that have diverted the flow of water.

Soils: In general, the higher the rate of infiltration, the lower the quantity of stormwater runoff. Fine—textured soils such as clay produce a higher rate of runoff than do coarse—textured soils such as sand. Sites having clay soils may require the construction of more elaborate drainage systems than sites having sandy soils. Exhibit B—2 contains a list of soils found in West Virginia and their respective hydrologic soil group.

Surface Cover: The type of cover and its condition affects runoff volume through its influence on the infiltration rate of the soil. Fallow land yields more runoff than forested or grass land for a given soil type.

The foliage and its litter maintain the soil's infiltration potential by preventing the sealing of the soil surface from the impact of the raindrops. Some of the raindrops are maintained on the surface of the foliage, increasing their chance of being evaporated back to the atmosphere. Some of the intercepted moisture takes a long time to drain from the plant down to the soil so that it is withheld from the initial period of runoff. Foliage also transpires moisture into the atmosphere thereby creating a moisture deficiency in the soil which must be replaced by rainfall before runoff occurs. Vegetation, including ground litter, forms numerous barriers along the path of the water flowing over the surface of the land which slows the water down and reduces its peak rate of runoff.

Covering areas with impervious material reduces surface storage and infiltration and thus increases the amount of runoff.

Time Parameters: Time is the parameter that is used to distribute the runoff into a hydrograph. The time is based on the velocities of flow through segments of the watershed. The slope of the land in the watershed is a major factor in determining the velocity. Two major parameters are time of concentration (T_c) and travel time of flow through the segments (T_t).

Storage in the Watershed: On very flat surfaces where ponding or swampy areas occur throughout the watershed, a considerable amount of the surface runoff may be retained in temporary storage, thus reducing the rate at which runoff will occur. Storage areas may be created to reduce the rate of runoff in an urbanizing area. These can be effective sediment traps as well as flood detention structures if permanently maintained in the watershed.

Methods of Determining Runoff

Many different methods of computing runoff have been developed. Some of the methods and limitations of each are listed below.

1. SCS National Engineering Handbook Section 4, Hydrology, may be used to develop hydrographs and peak discharge from any drainage area, including those larger than 20 square miles. The methods contained in this handbook are quite complex and should not be attempted by those who are untrained in hydrology.

2. Computer Program for Project Formulation—Hydrology, SCS—TR—20, utilizes hydrologic soil—cover complexes to determine runoff volumes and unit hydrographs to determine peak rates of discharge. Factors included in the method are 24—hour rainfall amount, a given rainfall distribution, runoff curve numbers, time of concentration, travel time, and drainage area. This procedure probably should not be used for drainage areas more than 20 square miles. It is very useful for large drainage basins, especially when there are a series of structures or several tributaries to be studied.

3. The SCS Engineering Field Handbook, Chapter 2, Procedures for Determining Peak Discharge, is valid for small rural

watersheds. The time of concentration for the non—urbanized area is estimated using a formula based on flow length, runoff curve number and average watershed slope. Chapter 2 procedures are applicable to drainage areas that range from 1 to 2000 acres. Tables, figures, exhibits, and worksheets are included for a quick and reliable way to estimate peak discharge and runoff for a range of rainfall amounts, soil types, land use and cover conditions.

4. The SCS—TR—55 tabular method is an approximation of the more detailed SCS—TR—20 method. The tabular method can be used for watersheds where hydrographs are needed to measure non—homogeneous runoff, i.e., the watershed is divided into subareas. It is especially applicable for measuring the effects of changed land use in a part of a watershed. It can also be used to determine the effects of structures and combinations of structures, including channel modifications, at different locations in a watershed. The tabular method should not be used when large changes in the curve number occur within subareas.

   For most watershed conditions, however, this procedure is adequate to determine the effects of urbanization on peak rates of discharge for subareas with "T_c" less than two hours.

5. The SCS—TR—55 Graphical Peak Discharge Method calculates peak discharge from hydrograph analyses using TR—20, Computer Program for Project Formulation. This method demonstrates a procedure for estimating depth and peak rates of runoff from small watersheds. The watershed must be hydrologically homogeneous, that is land use, soils, and cover are distributed uniformly throughout the watershed. The time of concentration for the watershed is estimated using the computed flow velocities for the sheet flow, shallow concentrated flow and channel flow. These values may range from 0.1 to 10 hours. This method was selected for inclusion in this manual to use in designing erosion and sediment control measures.

SCS Runoff Curve Number Method

The SCS Runoff Curve Number (CN) method is described in detail in National Engineering Handbook — Chapter 4 (NEH—4). The SCS runoff equation is

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad \text{[Eq. B—1]}$$

where

Q = runoff (in),

P = rainfall (in),

S = potential maximum retention after runoff begins (in), and

I_a = initial abstraction (in).

Initial abstraction (I_a) is all losses before runoff begins. It includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration. I_a is highly variable but generally is correlated with soil and cover parameters. Through studies of many small agricultural watersheds, I_a was found to be approximated by the following empirical equation:

$$I_a = 0.2S \qquad \text{[Eq. B—2]}$$

By removing I_a as an independent parameter, this approximation allows use of a combination of S and P to produce a unique runoff amount. Substituting equation B—2 into equation B—1 gives

$$Q = \frac{(P - 0.2S)^2}{(P+0.8S)} \qquad \text{[Eq. B—3]}$$

S is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by

$$S = \frac{1000}{CN} - 10 \qquad \text{[Eq. B—4]}$$

Figure B—1 solves equation B—3 for a range of CN's and rainfall.

Factors Considered in Estimating Runoff Curve Numbers

The major factors that determine CN are the hydrologic soil group (HSG), cover type, treatment, hydrologic condition, and antecedent runoff condition (ARC). Another factor considered is whether impervious areas outlet directly to the drainage system (connected) or whether the flow spreads over pervious areas before entering the drainage system (unconnected). Figure B—2 is provided to aid in selecting the appropriate figure or table for determining curve numbers.

CN's in Tables B—1, B—2 and B—3 represent average antecedent runoff condition for urban, cultivated agricultural and other agricultural uses. These tables assume impervious areas are directly connected. The following sections explain how to determine CN's and how to modify them for urban conditions.

Hydrologic Soil Groups: Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into four HSG's (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting. Exhibit B—2 defines the four groups and provides a list of the soils in West Virginia and their group classification. The soils in the area of interest may be identified from a county soil survey report, which can be obtained from local SCS offices or soil and water conservation district offices.

Most urban areas are only partially covered by impervious surfaces; the soil remains an important factor in runoff estimates. Urbanization has a greater effect on runoff in watersheds with soils having high infiltration rates (sands and gravels) than in watersheds predominantly of silts and clays, which generally have low infiltration rates.

Any disturbance of a soil profile can significantly change its infiltration characteristics. With urbanization, native soil profiles may be mixed or removed, or fill material from other areas may be introduced. Therefore, a method based on soil texture is given in Exhibit B—2 for determining the HSG classification for disturbed soils.

Cover Type: Tables B—1, B—2 and B—3 address most cover types such as vegetation, bare soil, and impervious surfaces. There are a number of methods for determining cover type. The most common are field reconnaissance, aerial photographs, and land use maps.

Treatment: Treatment is a cover type modifier (used only in Table B—2) to describe the management of cultivated agricultural lands. It includes mechanical practices, such as contouring and terracing, and management practices, such as crop rotations and reduced or no tillage.

Hydrologic Condition: Hydrologic condition indicates the effects of cover type and treatment on infiltration and runoff and is generally estimated from density of plant and residue cover on sample areas. Good hydrologic condition indicates that the soil usually has a low runoff potential for that specific hydrologic soil group, cover type and treatment. Some factors to consider in estimating the effect of cover on infiltration and runoff are (a) canopy or density of lawns, crops, or other vegetative areas; (b) amount of year—round cover; (c) amount of grass or close—seeded legumes in rotations; (d) percent of residue cover; and (e) degree of surface roughness.

Antecedent Runoff Condition: The index of runoff potential before a storm event is the antecedent runoff condition (ARC). ARC is an attempt to account for the variation in CN at a site from storm to storm. CN for the average ARC at a site is the median value as taken from sample rainfall and runoff data. The CN's in Tables B—1, B—2 and B—3 are for the average ARC, which is primarily used for design applications. See the SCS NEH—4 for more detailed discussion of storm—to—storm variation and a demonstration of upper and lower enveloping curves.

Urban Impervious Area Modifications: Several factors, such as the percentage of impervious area and the means of conveying runoff from impervious areas to the drainage system, should be considered in computing CN for urban areas. For example, do the impervious areas connect directly to the drainage system, or do they outlet onto lawns or other pervious areas where infiltration can occur?

Connected Impervious Areas: An impervious area is considered connected if runoff from it flows directly into the drainage system. It is also considered connected if runoff from it occurs as concentrated shallow flow that runs over a pervious area and then into a drainage system.

Urban CN's, Table B—1, were developed for typical land use relationships based on specific assumed percentages of impervious area. These CN values were developed on the assumptions that (a) pervious urban areas are equivalent to pasture in good hydrologic condition and (b) impervious areas have a CN of 98 and are directly connected to the drainage system. Some assumed percentages of impervious areas are shown in Table B—1.

If all of the impervious area is directly connected to the drainage system, but the impervious area percentages or the pervious land use assumptions in Table B—1 are not applicable, use Figure B—3 to compute a composite CN. For example, Table B—1 gives a CN of 70 for a 1/2—acre lot in hydrologic soil group B, with an assumed impervious area of 25 percent. However, if the lot has 20 percent impervious area and a pervious area CN of 61, the composite CN obtained from Figure B—3 is 68. The CN difference between 70 and 68 reflects the difference in percent impervious area.

Unconnected Impervious Areas: Runoff from these areas is spread over a pervious area as sheet flow. To determine CN when all or part of the impervious area is not directly connected to the drainage system, (1) use Figure B—4 if total impervious area is less than 30 percent or (2) use Figure B—3 if the total impervious area is equal to or greater than 30 percent, because the absorptive capacity of the remaining pervious areas will not significantly affect runoff.

When impervious area is less than 30 percent, obtain the composite CN by entering the right half of Figure B—4 with the percentage of total impervious area and the ratio of total unconnected impervious area to total impervious area. Then move left to the appropriate pervious CN and read down to find the composite CN. For example, for a 1/2—acre lot with 20 percent total impervious area (75 percent of which is unconnected) and a pervious CN of 61, the composite CN from Figure B—4 is 66. If all of the impervious area is connected, the resulting CN (from Figure B—3) would be 68.

Figure B-1 — Solution to Runoff Equation

(Reprinted from: 210-VI-TR-55, Second Ed., June 1986)

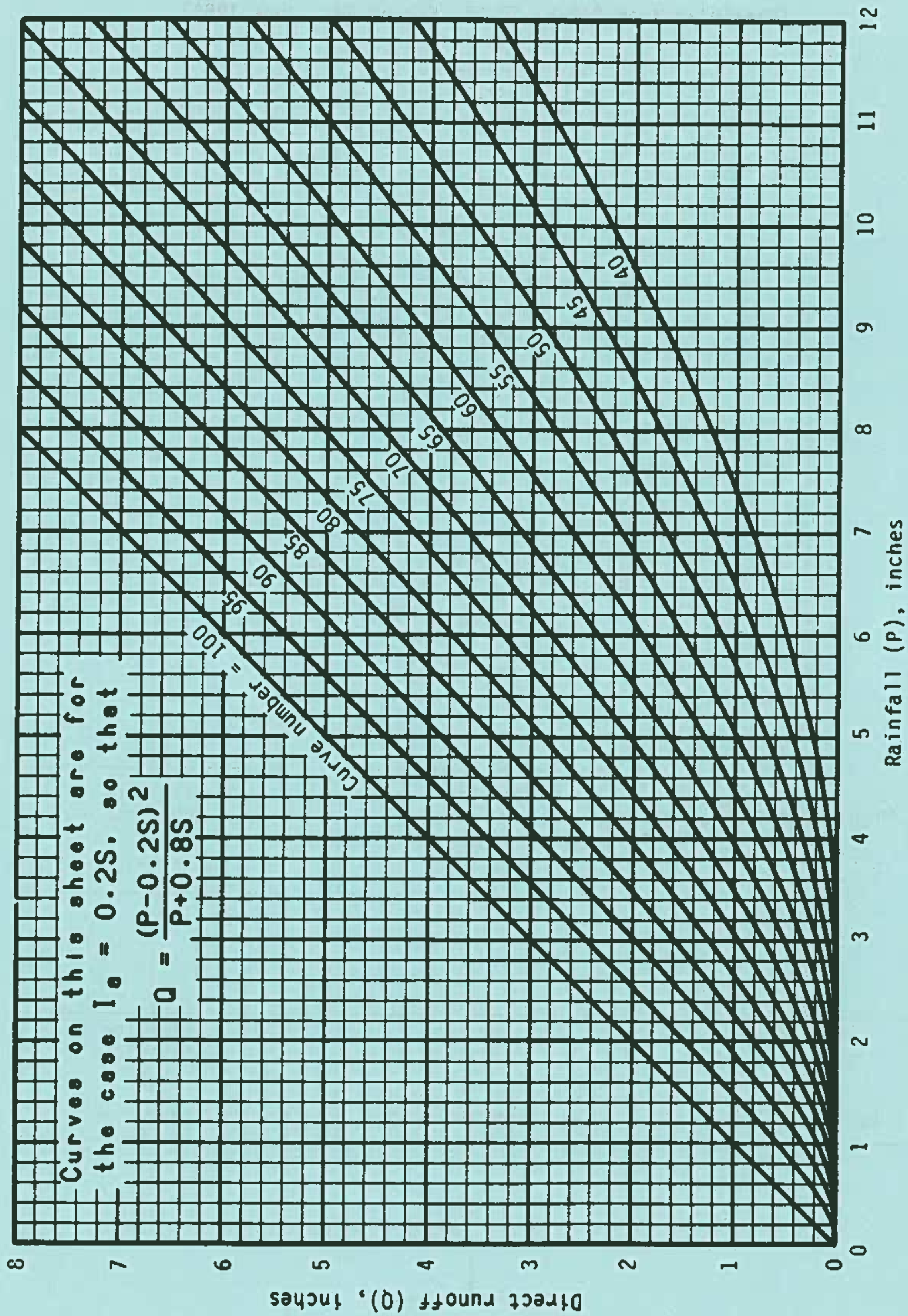


Figure B-2

Flow Chart for Selecting Appropriate Figure or Table for Determining Runoff Curve Numbers

(Reprinted from 210-VI-TR-55, Second Ed., June 1986)

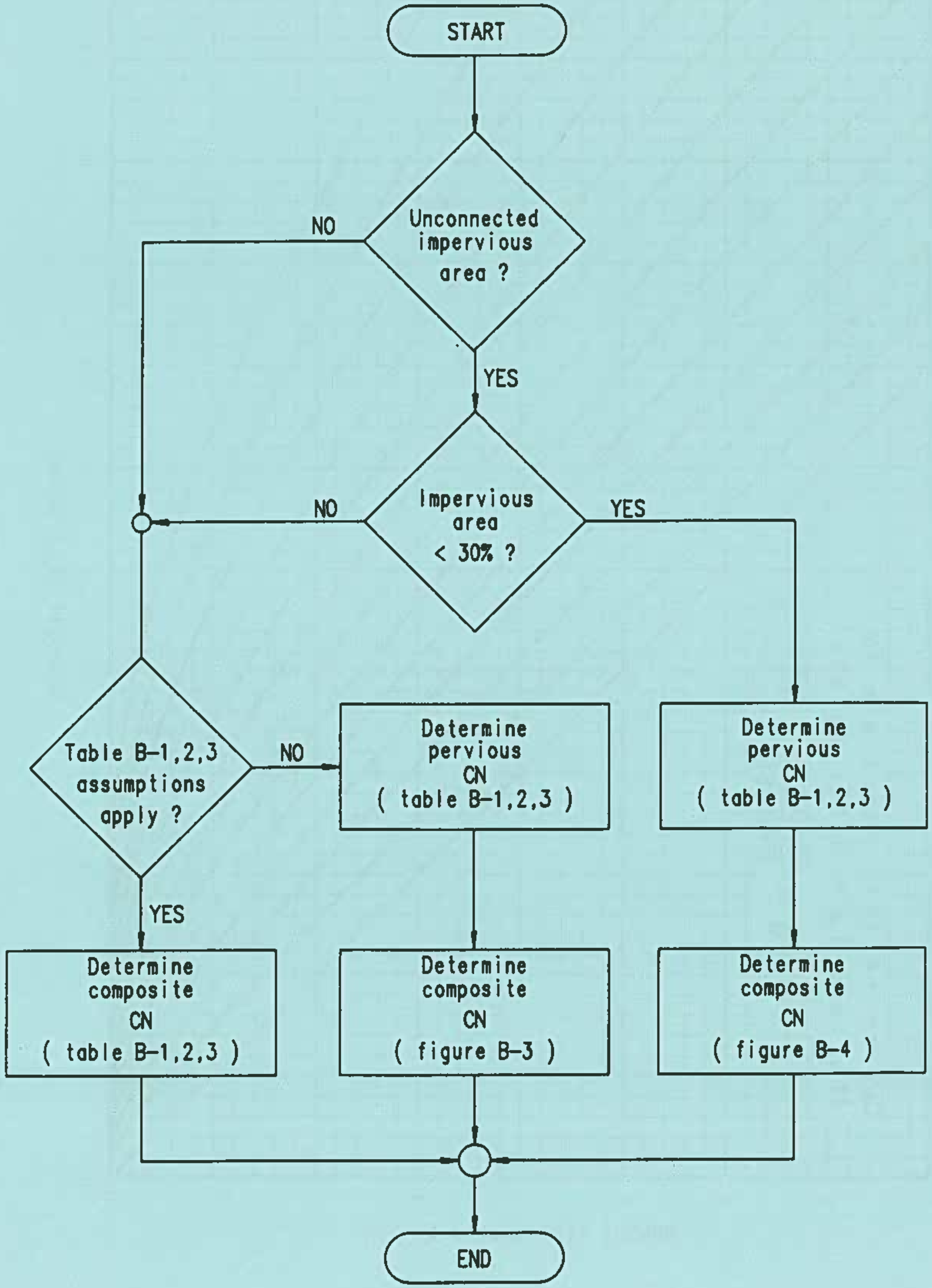


Table B-1 — Runoff Curve Numbers for Urban Areas [1]

(Reprinted from: 210-VI-TR-55, Second Ed., June 1986)

Cover Description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas					
Paved: parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved: curbs and storm sewers (excluding right of way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	98
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscape (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with a 1 to 2 inch sand or gravel mulch and basin boarders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in Table B-3)					

[1] Average runoff condition and $I_a = 0.2S$

[2] The average percent impervious area shown was used to develop composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using Figure B-3 or B-4.

[3] CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

[4] Composite CN's for natural desert landscaping should be computed using Figure E-3 or B-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic Condition.

[5] Composite CN's to use for the design of temporary measures during grading and construction should be computed using Figure B-3 or B 4 based on the degree of development (impervious area percentage) and the CN's for newly graded pervious areas.

Table B-2 — Runoff Curve Numbers for Cultivated Agricultural Lands [1]

(Reprinted from: 210-VI-TR-55, Second Ed., June 1986)

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment [2]	Hydrologic condition [3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

[1] Average runoff condition, and $I_a = 0.2S$

[2] Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.

[3] Hydrologic condition is based on combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes in rotation, (d) percent of residue cover on the land surface (good-20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table B-3 — Runoff Curve Numbers for Other Agricultural Lands [1]

(Reprinted from: 210-VI-TR-55, Second Ed., June 1986)

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range-continous forage for grazing. [2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow-continous grass, protected from grazing and generally mowed for hay.		30	58	71	78
Brush—brush—weed—grass mixture with brush the major element [3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[4]	48	65	73
Woods-grass combination (orchard or tree farm) [5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods [6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads-buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

[1] Average runoff condition, and $I_a = 0.2S$.

[2] **Poor:** < 50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.

[3] **Poor:** < 50% ground cover.
Fair: 50 to 75% ground cover.
Good: > 75% ground cover.

[4] Actual curve number is less than 30; use CN = 30 for runoff computations.

[5] CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

[6] **Poor:** Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Figure B-3

Composite CN with Connected Impervious Area

(Reprinted from: 210-VI-TR-55, Second Ed., June 1986)

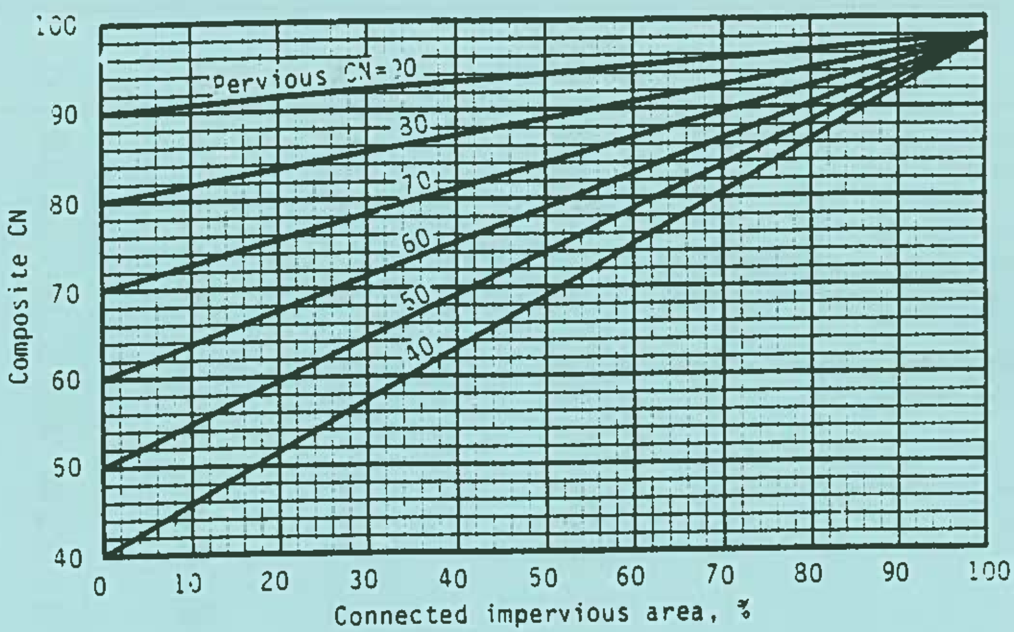
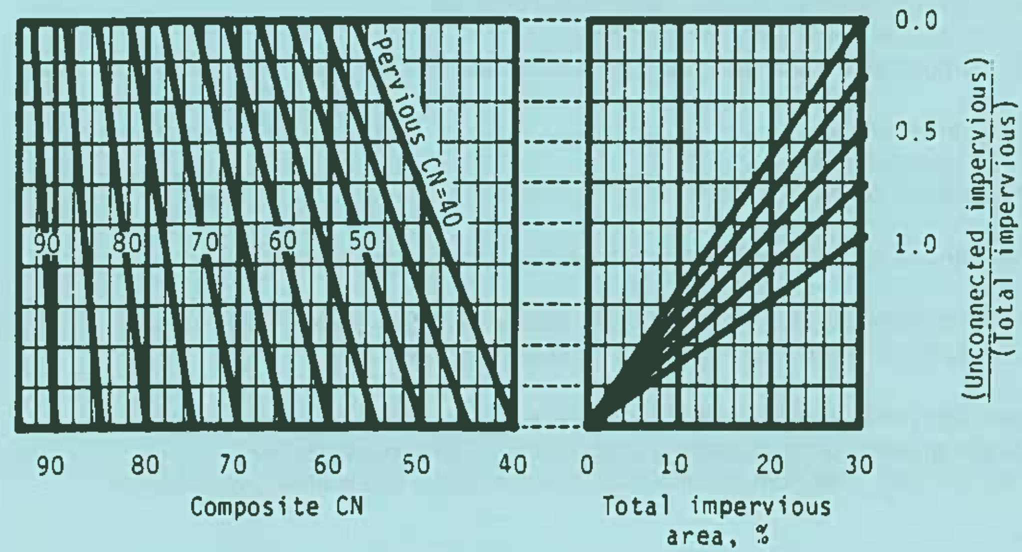


Figure B-4

Composite CN with Unconnected Impervious Areas and Total Impervious Areas less than 30%

(Reprinted from: 210-VI-TR-55, Second Ed., June 1986)



Runoff Determination

When CN and the amount of rainfall have been determined for the watershed, determine runoff by using Figure B—1.

Limitations: Curve numbers describe average conditions that are useful for design purposes. If the rainfall event used is a historical storm, the modeling accuracy decreases.

Use the runoff curve number equation with caution when recreating specific features of an actual storm. The equation does not contain an expression for time and, therefore, does not account for rainfall duration or intensity.

The user should understand the assumption reflected in the initial abstraction term (I_a) and should ascertain that the assumption applies to the situation. I_a, which consists of interception, initial infiltration, surface depression storage, evapotranspiration, and other factors, was generalized as 0.2S based on data from agricultural watersheds (S is the potential maximum retention after runoff begins). This approximation can be especially important in an urban application because the combination of impervious areas with pervious areas can imply a significant initial loss that may not take place. The opposite effect, a greater initial loss, can occur if the impervious areas have surface depressions that store some runoff. To use a relationship other than $I_a = 0.2S$, one must redevelop equation B—3, Figure B—1 and Tables B—1, B—2 and B—3 by using the original rainfall—runoff data to establish new S or CN relationships for each cover and hydrologic soil group.

Runoff from snowmelt or rain on frozen ground cannot be estimated using these procedures.

The CN procedure is less accurate when runoff is less than 0.5 inch. As a good check, use another procedure to determine runoff.

The SCS runoff procedures apply only to direct surface runoff: do not overlook large sources of subsurface flow or high ground water levels that contribute to runoff. These conditions are often related to HSG A soils and forest areas that have been assigned relatively low curve numbers. Good judgement and experience based on stream gage records are needed to adjust CN's as conditions warrant. When the weighted CN is less than 40, use another procedure to determine runoff.

Examples

Four examples illustrate the procedure for computing runoff curve number (CN) and runoff (Q) in inches. Worksheet 2, Figure B—5, is provided to assist users. Figures B—6 through Figure B—9 represent the use of Worksheet 2 for each example. All four examples are based on the same watershed and the same storm event.

The watershed covers 250 acres in Marion County, West Virginia. Seventy percent (175 acres) is a Gilpin soil, which is in hydrologic soil group C. Thirty percent (75 acres) is a Culleoka soil, which is in group B. The event is a 25—year frequency, 24—hour storm with a total rainfall of 4.63 inches.

Cover type and conditions in the watershed are different for each example. The examples, therefore, illustrate how to compute CN and Q for various situations of proposed, planned, or present development.

Example 1:
The present cover type is pasture in good hydrologic condition. See Figure B—6 for Worksheet 2 information.

Example 2:
Seventy percent (175 acres) of the watershed, consisting of all the Culleoka soil and 100 acres of the Gilpin soil, is 1/2—acre residential lots with lawns in good hydrologic condition. The rest of the watershed is scattered open space in good hydrologic condition. See Figure B—7.

Example 3:
This example is the same as Example 2, except that the 1/2—acre lots have a total impervious area of 35 percent. For these lots, the pervious area is lawns in good hydrologic condition. Since the impervious area percentage differs from the percentage assumed in Table B—1, use Figure B—3 to compute CN. See Figure B—8.

Example 4:
This example is also based on Example 2, except that 50 percent of the impervious area associated with the 1/2—acre lots on the Gilpin soil is "unconnected," that is, it is not directly connected to the drainage system. For these lots, the pervious area CN (lawn, good condition) is 74 and the impervious area is 25 percent. Use Figure B—4 to compute the CN for these lots. CN's for the 1/2—acre lots on Culleoka soil and the open space on Gilpin soil are the same as those in Example 2. See Figure B—9.

Figure B-5

Worksheet 2: Runoff Curve Number and Runoff

(Reprinted from 210-VI-TR-55, Second Ed., June 1986)

Project ______________________ By ______________ Date ________

Location ________________________ Checked ________ Date ________

Circle one: Present Developed ___________________________________

1. Runoff curve number (CN)

Soil name and hydrologic group Exhibit B-2	Cover description (cover type, treatment, & hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/			Area ☐ acres ☐ mi² ☐ %	Product of CN x area
		T2/ TABLE B-1	TABLE B-2	TABLE B-3		
				Totals =		

1/ Use only one CN source per line.
2/ Modify by using Figure B-3 or B-4 as needed.

CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = ______ = ______, Use CN = ☐

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency .... yr			
Rainfall, P (24-hour) .... in			
Runoff, Q .... in			

(Use P and CN with fig. B-1, or eqs. B-3 and B-4.)

Figure B-6

Worksheet 2: Runoff Curve Number and Runoff

Worksheet 2 for Example 1

Project Hicory Hill By SEC Date 1-7-92

Location Marion County, WV Checked ROA Date 1-7-92

Circle one: (Present) Developed

1. Runoff curve number (CN)

Soil name and hydrologic group Exhibit B-2	Cover description (cover type, treatment, & hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ TABLE B-1 [2/]	CN 1/ TABLE B-2	CN 1/ TABLE B-3	Area ☐ acres ☐ mi² ☐ %	Product of CN x area
Culleoka B	Pasture, good condition			61	30	1830
Gilpin C	Pasture, good condition			74	70	5180
				Totals =	100	7010

1/ Use only one CN source per line.
2/ Modify by using Figure B-3 or B-4 as needed.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{7010}{100}$ = 70.1, Use CN = 70

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ..... yr	25		
Rainfall, P (24-hour) ..... in	4.63		
Runoff, Q ..... in	1.80		

(Use P and CN with fig. B-1, or eqs. B-3 and B-4.)

Figure B-7

Worksheet 2: Runoff Curve Number and Runoff

Worksheet 2 for Example 2

Project Hicory Hill By SEC Date 1-7-92

Location Marion County, WV Checked ROA Date 1-7-92

Circle one: Present (Developed) 175 Acres Residential

1. Runoff curve number (CN)

Soil name and hydrologic group Exhibit B-2	Cover description (cover type, treatment, & hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/			Area ☐ acres ☐ mi² ☐ %	Product of CN x area
		TABLE B-1 2/	TABLE B-2	TABLE B-3		
Culleoka B	1/2 acre lots, good cond. 25% impervious	70			75	5250
Gilpin C	1/2 acre lots, good cond. 25% impervious	80			100	8000
Gilpin C	open space, good cond.	74			75	5550
				Totals =	250	18,880

1/ Use only one CN source per line.
2/ Modify by using Figure B-3 or B-4 as needed.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{18,880}{250}$ = 75.2, Use CN = 75

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency .... yr	25		
Rainfall, P (24-hour) .... in	4.63		
Runoff, Q .... in	2.20		

(Use P and CN with fig. B-1, or eqs. B-3 and B-4.)

Figure B-8

Worksheet 2: Runoff Curve Number and Runoff

Worksheet 2 for Example 3

Project Hicory Hill By SEC Date 1-7-92

Location Marion County, WV Checked ROA Date 1-7-92

Circle one: Present (Developed)

1. Runoff curve number (CN)

Soil name and hydrologic group Exhibit B-2	Cover description (cover type, treatment, & hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/			Area ☐ acres ☐ mi² ☐ %	Product of CN x area
		T2/ TABLE B-1	TABLE B-2	TABLE B-3		
Culleoka B	1/2 acre lots, good cond. 35% impervious	74			75	5550
Gilpin C	1/2 acre lots, good cond. 35% impervious	82			100	8200
Gilpin C	open space, good cond.	74			75	5550
				Totals =	250	19,300

1/ Use only one CN source per line.
2/ Modify by using Figure B-3 or B-4 as needed.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{19,300}{250}$ = 77.2, Use CN = 77

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency .... yr	25		
Rainfall, P (24-hour) .... in	4.63		
Runoff, Q .... in	2.35		

(Use P and CN with fig. B-1, or eqs. B-3 and B-4.)

Figure B-9

Worksheet 2: Runoff Curve Number and Runoff

Worksheet 2 for Example 4

Project Hicory Hill By SEC Date 1-7-92

Location Marion County, WV Checked ROA Date 1-7-92

Circle one: Present (Developed)

1. Runoff curve number (CN)

Soil name and hydrologic group Exhibit B-2	Cover description (cover type, treatment, & hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/			Area ☐ acres ☐ mi² ☐ %	Product of CN x area
		T2/ TABLE B-1	TABLE B-2	TABLE B-3		
Culleoka B	1/2 acre lots, good cond. 25% impervious, connected	70			75	5250
Gilpin C	1/2 acre lots, good cond. 25% impervious, 50% uncon.	78			100	7800
Gilpin C	open space, good cond.	74			75	5550
				Totals =	250	18,600

1/ Use only one CN source per line.
2/ Modify by using Figure B-3 or B-4 as needed.

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{18,600}{250}$ = 74.4, Use CN = 74

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency .... yr	25		
Rainfall, P (24-hour) .... in	4.63		
Runoff, Q .... in (Use P and CN with fig. B-1, or eqs. B-3 and B-4.)	2.10		

Time of Concentration and Travel Time

Travel time (T_t) is the time it takes water to travel from one location to another in a watershed. T_t is a component of time of concentration (T_c) which is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed. T_c is computed by summing all the travel times for consecutive components of the drainage conveyance system.

T_c influences the shape and the peak of the runoff hydrograph. Urbanization usually decreases T_c, thereby increasing the peak discharge. But T_c can be increased as a result of (a) ponding behind small or inadequate drainage systems, including storm drain inlets and road culverts, or (b) reduction of land slope through grading.

Factors Affecting Time of Concentration and Travel Time

Surface Roughness: One of the most significant effects of urban development on flow velocity is less retardance to flow. This is, undeveloped areas with very slow and shallow overland flow through vegetation become modified by urban development: the flow is then delivered to streets, gutters, and storm sewers that transport runoff downstream more rapidly. Travel time through the watershed is generally decreased.

Channel Shape and Flow Patterns: In small non—urban watersheds, much of the travel time results from overland flow in upstream areas. Typically, urbanization reduces overland flow lengths by conveying storm runoff into a channel as soon as possible. Since designed channels have efficient hydraulic characteristics, runoff flow velocity increases and travel time decreases.

Slope: Slopes may be increased or decreased by urbanization, depending on the extent of site grading or the extent to which storm sewers and street ditches are used in the design of the water management system. Slope will tend to increase when channels are straightened and decrease when overland flow is directed through storm sewers, street gutters, and diversions.

Computation of Travel Time and Time of Concentration

Water moves through a watershed as sheet flow, shallow concentrated flow, open channel flow, or some combination of these. The type that occurs is a function of the conveyance system and is best determined by field inspection.

Travel time (T_t) is the ratio of flow length to flow velocity:

$$T_t = \frac{L}{3600\ V} \qquad \text{[Eq. B—5]}$$

where

T_t = travel time (hr),

L = flow length (ft),

V = average velocity (ft/s), and

3600 = conversion factor from seconds to hours

Time of concentration (T_c) is the sum of T_t values for the various consecutive flow segments:

$$T_c = T_{t1} + T_{t2} + ...T_{tm} \qquad \text{[Eq. B—6]}$$

where

T_c = time of concentration (hr) and

m = number of flow segments.

Sheet Flow: Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table B—4 gives Manning's n values for sheet flow for various surface conditions.

For sheet flow of less than 300 feet, use Manning's kinematic solution to compute T_t:

$$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,(S)^{0.4}} \qquad \text{[Eq. B—7]}$$

where

T_t = travel time (hr),

n = Manning's roughness coefficient, Table B—4

L = flow length (ft),

P_2 = 2—year, 24—hour rainfall (in), and

s = slope of hydraulic grade line (land slope, ft/ft).

This simplified form of Manning's kinematic solution is based on the following:

(1) shallow steady uniform flow,

(2) constant intensity of rainfall excess (that part of a rain available for runoff),

(3) rainfall duration of 24 hours, and

(4) minor effect of infiltration on travel time.

Rainfall depth can be obtained from Exhibit B—1.

TABLE B-4 — Roughness Coefficients

(MANNING'S n) for Sheet Flow	
Surface Description	n[1]
Smooth surfaces (concrete, asphalt, gravel or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover <20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prarie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The values are a composite of information compiled by Engman (1980)
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

Shallow Concentrated Flow; After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from Figure B—10 in which average velocity is a function of watercourse slope and type of channel. tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining velocity in Figure B—10, use equation B—5 to estimate travel time for the shallow concentrated flow segment.

Open Channels: Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank—full elevation.

Manning's equation is

$$V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n} \qquad \text{[Eq. B—8]}$$

where

V = average velocity (ft/sec),

r = hydraulic radius (ft) and is equal to a/Pw,

a = cross sectional flow area (ft^2),

Pw = wetted perimeter (ft),

s = slope of the hydraulic grade line (channel slope, ft/ft), and

n = Manning's roughness coefficient for open channel flow.

Manning's "n" values for open channel flow can be obtained from standard textbooks. After average velocity is computed using equation B—8, T_t for the channel segment can be estimated using equation B—5.

Figure B-10

Average Velocities for Estimating Travel Time for Shallow Concentrated Flow

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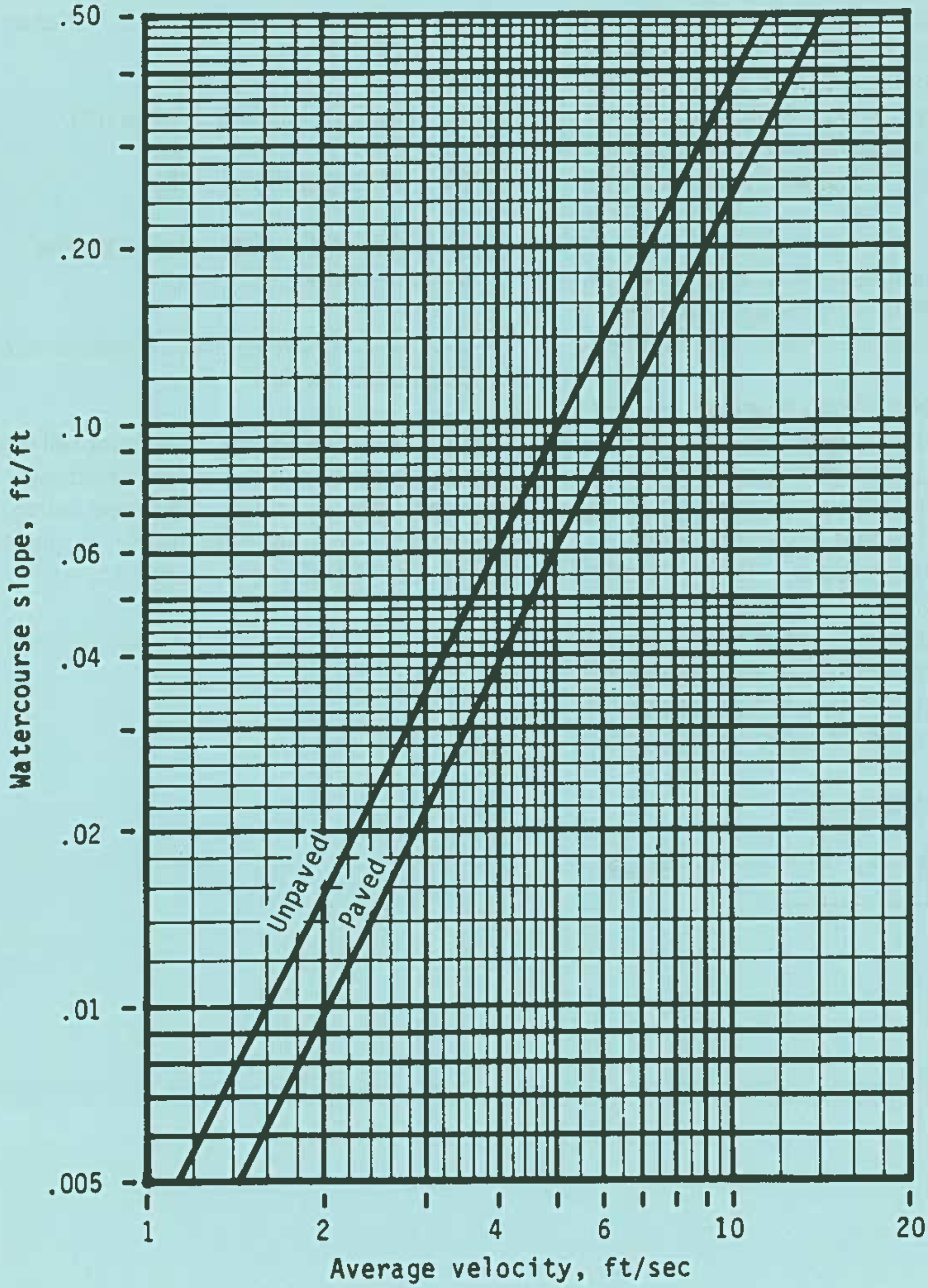


Reservoirs or Lakes: Sometimes it is necessary to estimate the velocity of flow through a reservoir or lake at the outlet of a watershed to determine travel time. This travel time is normally very small and can be assumed as zero.

Limitations: Manning's kinematic solution should not be used for sheet flow longer than 300 feet.

In watersheds with storm sewers, carefully identify the appropriate hydraulic flow path to estimate T_c. Storm sewers generally handle only a small portion of a large event. The rest of the peak flow travels by streets, lawns, and so on, to the outlet. Consult a standard hydraulics textbook to determine average velocity in pipes for either pressure or non—pressure flow.

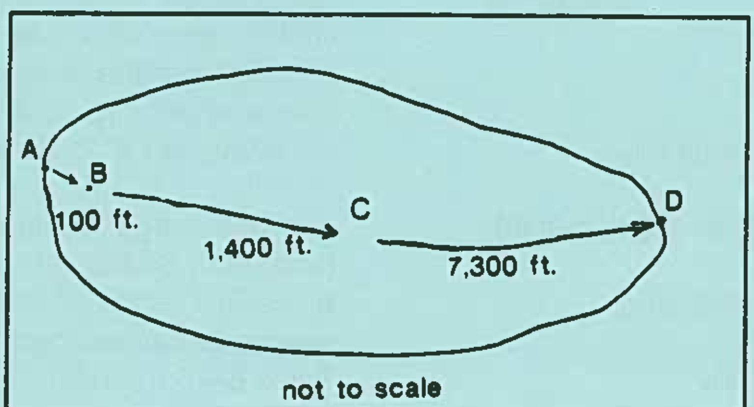
The minimum T_c used is 0.1 hour.

A culvert or bridge can act as a reservoir outlet if there is significant storage behind it. The procedures in TR—55 can be used to determine the peak flow upstream of the culvert. Detailed storage routing procedures should be used to determine the outlet through the culvert.

Figure B—11 provides Worksheet 3 for calculating Time of Concentration (T_c) or travel time (T_t).

Example 5:
The sketch below shows a watershed in Marion County, West Virginia. The problem is to compute T_c at the outlet of the watershed (point D). The 2—year 24—hour rainfall depth is 2.65 inches.

All three types of flow occur from the hydraulically most distant point (A) to the point of interest (D). To compute T_c, first determine T_t for each segment from the following information:



Segment AB: Sheet flow; dense grass; slope (s) = 0.01 ft/ft: and length (L) = 100 ft.

Segment BC: Shallow concentrated flow; unpaved; s = 0.01 ft/ft; and L = 1400 ft.

Segment CD: Channel flow; Manning's n = .05; flow area (a) = 27 ft^2; wetted perimeter (pw) = 28.2 ft;s = 0.005 ft/ft; and L = 7300 ft.

See Figure B—12 for the computations made on Worksheet 3 for Example 5.

Graphical Peak Discharge Method

The Graphical method was developed from hydrograph analyses using TR—20, "Computer Program for Project Formulation—Hydrology". The peak discharge equation used is:

$$qp = qu\, A_m\, Q\, F_p \qquad \text{[Eq. B—9]}$$

where

qp = peak discharge (cfs);

qu = unit peak discharge (csm/in);

A_m = drainage area (mi^2);

Q = runoff (in); and

F_p = pond and swamp adjustment factor.

The input requirements for the Graphical method are as follows:

(1) T_c (hr),
(2) drainage area (mi^2),
(3) 24—hour rainfall (in), and
(4) CN.

If pond and swamp areas are spread throughout the watershed and are not considered in the T_c computation, an adjustment for pond and swamp areas is also needed.

Peak Discharge Computation

For a selected rainfall frequency, the 24—hour rainfall (P) is obtained from Exhibit B—1. CN and total runoff (Q) for the watershed were computed earlier. The CN is used to determine the initial abstraction (I_a) from Table B—5. I_a/P is then computed.

If the computed I_a/P ratio is outside the range shown in Figure B—16, then the limiting value should be used. If the ratio falls between the limiting values, use linear interpolation. Figure B—13 illustrates the sensitivity of I_a/P to CN and P.

Peak discharge per square mile per inch of runoff (qu) is obtained from Figure B—16 by using T_c and I_a/P ratio. The pond and swamp adjustment factor is obtained from Table B—6 (rounded to the nearest Table value). Use Worksheet 4, Figure B—14, to aid in computing the peak discharge using the Graphical method.

Figure B-11

Worksheet 3: Time of Concentration (T_c) or Travel Time (T_t)

(Reprinted from: 210-VI-TR-55, Second Ed., June 1986)

Project ______________________ By ______ Date __________
Location ______________________ Checked ______ Date __________
Circle one: Present Developed ______________________
Circle one: T_c T_t through subarea ______________________

Sheet flow (Applicable to T_c only) — Segment ID

Item	Unit	Segment
1. Surface description (table B-4)		
2. Manning's roughness coeff., n (table B-4)		
3. Flow length, L (total L < 300 ft)	ft	
4. Two-yr 24-hr rainfall, P_2	in	
5. Land slope, s	ft/ft	
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{\,0.5}\, s^{0.4}}$ Compute T_t	hr	

Shallow concentrated flow — Segment ID

Item	Unit	Segment
7. Surface description (paved or unpaved)		
8. Flow length, L	ft	
9. Watercourse slope, s	ft/ft	
10. Average velocity, V (figure B-10)	ft/s	
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	

Channel flow — Segment ID

Item	Unit	Segment
12. Cross sectional flow area, a	ft^2	
13. Wetted perimeter, P_w	ft	
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft	
15. Channel slope, s	ft/ft	
16. Manning's roughness coeff., n		
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$ Compute V	ft/s	
18. Flow length, L	ft	
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	

20. Watershed or subarea t_c or t_t (add t_t in steps 6, 11, and 19) .. hr

Figure B-12

Worksheet 3: Time of Concentration (T_c) or Travel Time (T_t)

Worksheet 3 for Example 5

Project Hickory Hill By SEC Date 1-7-92
Location Marion County, WV Checked ROA Date 1-7-92
Circle one: Present (Developed) [circled]
Circle one: (T_c) [circled] T_t through subarea

Sheet flow (Applicable to T_c only)	Segment ID.		AB
1. Surface description (table B-4)			Dense Grass
2. Manning's roughness coeff., n (table B-4)			0.24
3. Flow length, L (total L < 300 ft)		ft	100
4. Two-yr 24-hr rainfall, P_2		in	2.65
5. Land slope, s		ft/ft	0.01
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{\,0.5}\, s^{0.4}}$	Compute T_t	hr	0.34

Shallow concentrated flow	Segment ID.		BC
7. Surface description (paved or unpaved)			Unpav.
8. Flow length, L		ft	1400
9. Watercourse slope, s		ft/ft	0.01
10. Average velocity, V (figure B-10)		ft/s	1.6
11. $T_t = \frac{L}{3600\,V}$	Compute T_t	hr	0.24

Channel flow	Segment ID.		CD
12. Cross sectional flow area, a		ft^2	27
13. Wetted perimeter, P_w		ft	28.2
14. Hydraulic radius, $r = \frac{a}{P_w}$	Compute r	ft	0.957
15. Channel slope, s		ft/ft	0.005
16. Manning's roughness coeff., n			0.05
17. $V = \frac{1.49\, r^{2/3}\, s^{1/2}}{n}$	Compute V	ft/s	2.05
18. Flow length, L		ft	7300
19. $T_t = \frac{L}{3600\,V}$	Compute T_t	hr	0.99
20. Watershed or subarea t_c or t_t (add t_t in steps 6, 11, and 19)		hr	1.57

Figure B-13 — Variation of I_a/P for P and CN

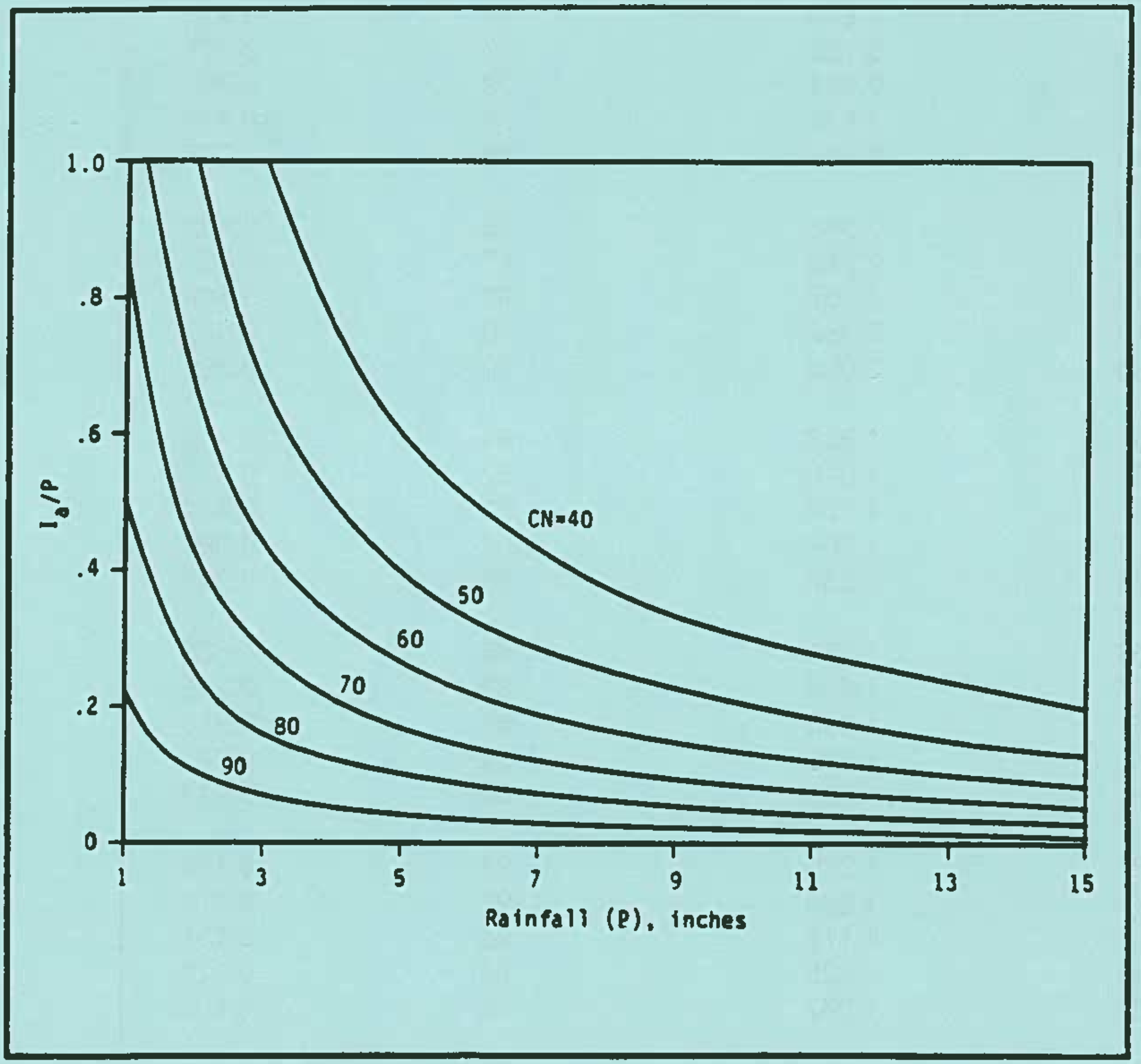


Table B-5 — I_a Values for Runoff Curve Numbers

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.637	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	98	0.041
69	0.899		

Exhibit B-2 — Hydrology: Soil Names and Hydrologic Soil Groups *(Continued)*

Lobdell — B	Sees — C
Lodi — B	Senecaville — B
Macove — B	Sensabaugh — B
Mandy — C	Sequatchie (use Chavies)
Markland — C	Sewell — C
Massanetta — B	Shelocta — B
McGary — C	Shouns — B
Meckesville — C	Simoda — C
Melvin — D	Skidmore — B
Mertz — C	Snowdog — C
Monongahela — C	Summers — B
Montevallo (use Weikert)	Taggart — C
Moshannon — B	Teas (use Cateache)
Murrill — B	Tilsit — C
Muskingum — C	Tioga — B
Myra — C	Toms — C
Nolin — B	Trussel — C
Nolo — D	Tumbez (use Opequon)
Opequon — C	Tygart — D
Orrville — C	Tyler — D
Otwell — C	Upshur — D
Peabody — D	Vandalia — D
Philo — B	Vincent — C
Pickaway (use Lawrence)	Waynesboro (use Braddock)
Pineville — B	**Weikert — C
Pope — B	Wellston (use Rayne)
Potomac — A	Westmoreland — B
Purdy — D	Wharton — C
Ramsey — D	Wheeling — B
Rayne — B	Woodfield — C
Robertsville — D	Wyatt (use Markland)
Rushtown — A	Zoar — C
Schaffenaker — A	
Sciotoville — C	

*For Weikert, use D where Bedrock is solid and impervious.

Contact the Soil Conservation Service State Soil Scientist for hydrologic group of soil variants.

Table B—6 — Adjustment factor (F_p) for pond and swamp areas that are spread throughout the watershed	
Percentage of pond and swamp areas	F_p
0.0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

Limitations: The Graphical method provides a determination of peak discharge only. If a hydrograph is needed or watershed subdivision is required, use the Tabular Hydrograph method in Technical Release #55. Use TR—20 if the watershed is very complex or a higher degree of accuracy is required.

The watershed must be hydrologically homogeneous, that is, describable by one CN. Land use, soils, and cover are distributed uniformly throughout the watershed.

The watershed may have only one main stream or, if more than one, the branches must have nearly equal T_c's.

The method cannot perform valley or reservoir routing.

The F_p factor can be applied only for ponds or swamps that are not in the T_c flow path.

Accuracy of peak discharge estimated by this method will be reduced if I_a/P values are used that are outside the range given in Figure B—16. The limiting I_a/P values are recommended for use.

This method should only be used if the weighted CN is greater than 40.

When this method is used to develop estimates of peak discharge for both present and developed conditions of a watershed, use the same procedure for estimating T_c.

T_c values with this method may range from 0.1 to 10 hours.

Example 6:
Compute the 25—year peak discharge for the 250—acre watershed described in Examples 2 and 5. Figure B—15 shows how Worksheet 4 is used to compute qp.

Figure B-14

Worksheet 4: Graphical Peak Discharge

(Reprinted from: 210-VI-TR-55, Second Ed., June 1986)

Project ______________________ By __________ Date __________

Location ______________________ Checked __________ Date __________

Circle one: Present Developed ______________________

1. Data:

   Drainage area .... A_m = ________ mi² (acres/640)

   Runoff curve number .... CN = ________ (From worksheet 2)

   Time of concentration .... T_c = ________ (From worksheet 3)

   Pond and swamp areas spread throughout watershed .... = ________ percent of A_m (________ acres or mi²)

	Storm #1	Storm #2	Storm #3
2. Frequency .... yr			
3. Rainfall, P (24-hour) .... in			
4. Initial abstraction, I_a .... in (Use CN with Table B-5)			
5. Compute I_a/P			
6. Unit peak discharge, q_u .... csm/in (Use T_c and I_a/P with Figure B-16)			
7. Runoff, Q .... in (From worksheet 2)			
8. Pond & swamp adjustment factor, ... F_p (Use percent pond and swamp area with Table B-6. Factor is 1.0 for zero percent pond and swamp area).			
9. Peak discharge, q_p ....cfs (Where $q_p = q_u A_m Q F_p$)			

Figure B-15

Worksheet 4: Graphical Peak Discharge

Worksheet 4 for Example 6

Project ____Hickory Hill____ By __SEC__ Date __1-7-92__

Location ___Marion County, WV___ Checked __ROA__ Date __1-7-92__

Circle one: Present (Developed) __________

1. Data:

   Drainage area .... A_m = 0.39 mi² (acres/640)

   Runoff curve number .... CN = 75 (From worksheet 2)

   Time of concentration .... T_c = 1.57 (From worksheet 3)

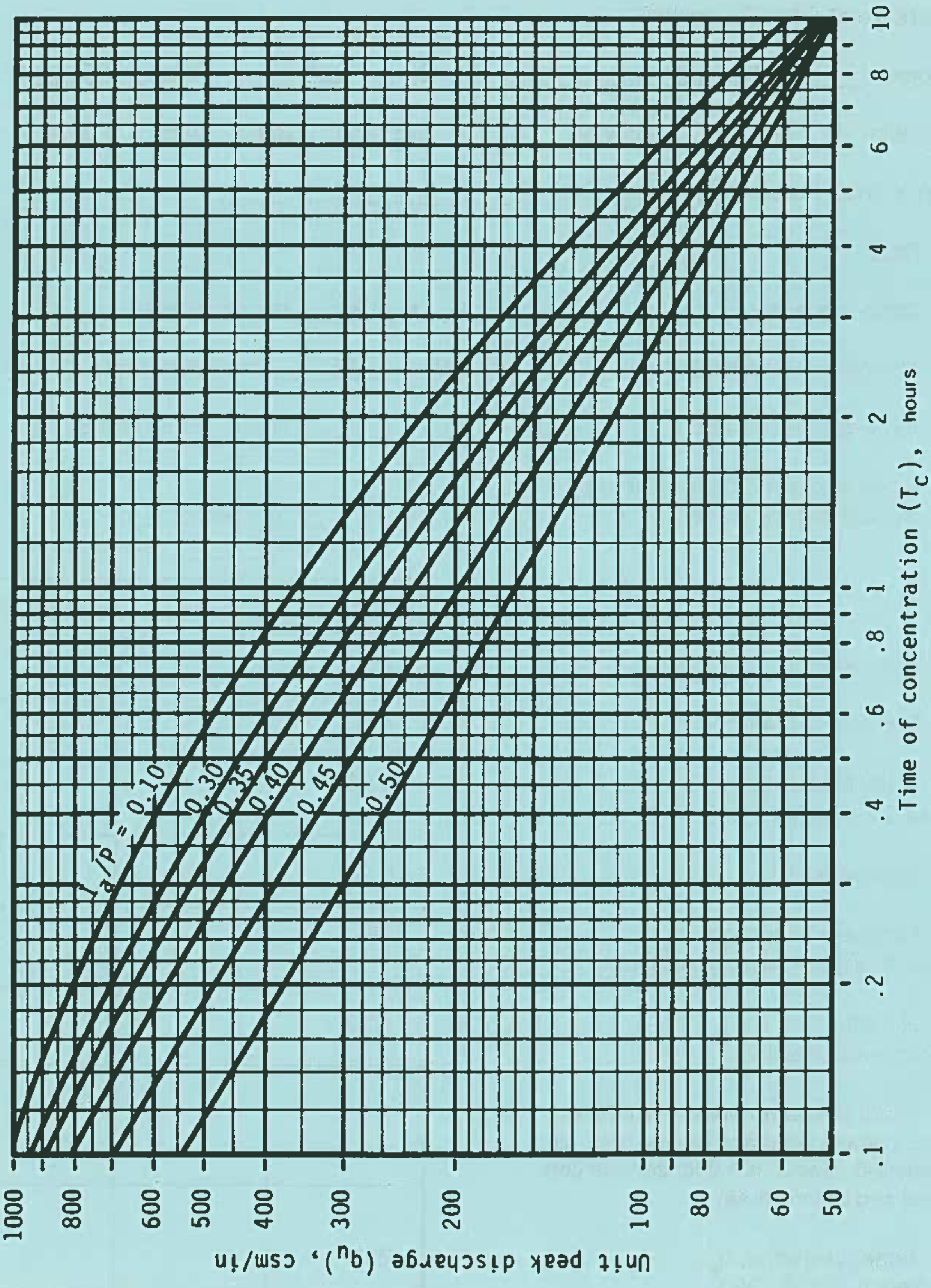
   Pond and swamp areas spread throughout watershed .... = ______ percent of A_m (______ acres or mi²)

	Storm #1	Storm #2	Storm #3
2. Frequency .... yr	25		
3. Rainfall, P (24-hour) .... in	4.63		
4. Initial abstraction, I_a .... in (Use CN with Table B-5)	0.667		
5. Compute I_a/P	0.14		
6. Unit peak discharge, q_u .... csm/in (Use T_c and I_a/P with Figure B-16)	255		
7. Runoff, Q .... in (From worksheet 2)	2.20		
8. Pond & swamp adjustment factor, ... F_p (Use percent pond and swamp area with Table B-6. Factor is 1.0 for zero percent pond and swamp area).	1.0		
9. Peak discharge, q_p .... cfs (Where $q_p = q_u A_m Q F_p$)	219		

Figure B-16

Unit Peak Discharge (qu) for SCS Type II Rainfall Distribution

(Reprinted from: 210-VI-TR-55, Second Ed., June 1986)



HYDROLOGY: Average 24-Hour Precipitation For Various Frequencies by Counties

County	Freq. (Yrs.)						
	1	2	5	10	25	50	100
Barbour	2.36	2.75	3.50	4.22	4.79	5.30	5.77
Berkeley	2.46	2.97	3.95	4.80	5.50	6.30	6.75
Boone	2.38	2.72	3.48	3.96	4.65	5.00	5.45
Braxton	2.36	2.70	3.44	4.10	4.70	5.10	5.65
Brooke	2.22	2.51	3.21	3.77	4.35	4.77	4.95
Cabell	2.38	2.68	3.42	3.90	4.52	4.92	5.25
Calhoun	2.32	2.63	3.37	3.88	4.56	4.91	5.40
Clay	2.35	2.69	3.45	4.00	4.65	5.04	5.55
Doddridge	2.30	2.61	3.33	3.90	4.57	4.92	5.40
Fayette	2.38	2.75	3.54	4.10	4.75	5.25	5.70
Gilmer	2.33	2.65	3.37	3.95	4.60	4.96	5.47
Grant	2.42	2.88	3.75	4.60	4.98	5.75	6.30
Greenbrier	2.45	2.85	3.75	4.40	4.92	5.60	6.00
Hampshire	2.45	2.93	3.85	4.70	5.20	5.90	6.55
Hancock	2.20	2.50	3.19	3.74	4.30	4.72	4.85
Hardy	2.48	2.94	3.90	4.75	5.40	5.95	6.70
Harrison	2.32	2.66	3.37	4.00	4.65	4.98	5.55
Jackson	2.32	2.60	3.35	3.82	4.45	4.84	5.17
Jefferson	2.50	3.10	4.20	4.95	5.70	6.60	7.00
Kanawha	2.35	2.66	3.44	3.93	4.60	4.96	5.40
Lewis	2.35	2.67	3.40	4.10	4.68	5.10	5.60
Lincoln	2.38	2.70	3.44	3.93	4.58	4.96	5.35
Logan	2.40	2.74	3.50	3.98	4.67	5.10	5.50
McDowell	2.43	2.81	3.64	4.15	4.79	5.32	5.70
Marion	2.30	2.65	3.36	3.99	4.63	4.97	5.50
Marshall	2.25	2.54	3.25	3.81	4.44	4.82	5.10
Mason	2.34	2.60	3.37	3.83	4.45	4.84	5.12
Mercer	2.45	2.85	3.60	4.25	4.87	5.48	5.85
Mineral	2.41	2.87	3.74	4.55	4.95	5.70	6.25
Mingo	2.42	2.77	3.54	4.00	4.69	5.15	5.52
Monongalia	2.30	2.66	3.37	4.00	4.65	4.97	5.50

HYDROLOGY: Average 24-Hour Precipitation For Various Frequencies by Counties

County	Freq. (Yrs.)						
	1	2	5	10	25	50	100
Monroe	2.47	2.89	3.82	4.45	4.97	5.75	6.25
Morgan	2.43	2.93	3.88	4.70	5.10	5.95	6.60
Nicholas	2.39	2.75	3.50	4.20	4.75	5.25	5.75
Ohio	2.24	2.52	3.22	3.79	4.39	4.78	5.00
Pendleton	2.46	2.93	3.85	4.70	5.30	5.85	6.55
Pleasants	2.27	2.54	3.28	3.78	4.42	4.79	5.15
Pocahontas	2.44	2.86	3.75	4.55	4.97	5.70	6.20
Preston	2.35	2.75	3.50	4.20	4.78	5.30	5.75
Putnam	2.34	2.65	3.40	3.86	4.51	4.89	5.25
Raleigh	2.40	2.77	3.56	4.10	4.75	5.25	5.68
Randolph	2.40	2.84	3.61	4.45	4.90	5.55	5.96
Ritchie	2.29	2.58	3.31	3.82	4.50	4.86	5.30
Roane	2.33	2.64	3.37	3.87	4.54	4.89	5.35
Summers	2.43	2.83	3.61	4.30	4.87	5.50	5.90
Taylor	2.34	2.72	3.43	4.10	4.72	5.12	5.65
Tucker	2.39	2.83	3.62	4.45	4.88	5.50	6.00
Tyler	2.28	2.55	3.28	3.80	4.46	4.84	5.20
Upshur	2.37	2.75	3.49	4.22	4.79	5.25	5.77
Wayne	2.42	2.74	3.49	3.95	4.58	4.99	5.40
Webster	2.39	2.76	3.55	4.30	4.82	5.40	5.85
Wetzel	2.28	2.58	3.28	3.85	4.50	4.86	5.25
Wirt	2.29	2.58	3.32	3.80	4.45	4.82	5.20
Wood	2.28	2.55	3.29	3.76	4.37	4.77	5.07
Wyoming	2.41	2.77	3.56	4.07	4.75	5.25	5.65

SCS Hydrologic Soil Groups — West Virginia

Soils are classified into hydrologic soil groups (HSG's) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The HSG's; which are A, B, C, and D; are one element used in determining runoff curve numbers.

The infiltration rate is the rate at which water enters the soil at the soil surface. It is controlled by surface conditions. HSG also indicates the transmission rate—the rate at which the water moves within the soil. This rate is controlled by the soil profile. Approximate numerical ranges for transmission rates shown in the HSG definitions were first published by Musgrave (USDA, 1955). The four groups are defined by SCS soil scientists as follows:

Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.

These soils have a moderate rate of water transmission.

Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water, and soils with moderately fine to fine texture. These soils have a low rate of water transmission.

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a high permanent water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission.

Disturbed Soil Profiles

As a result of urbanization, the soil profile may be considerably altered and the listed group classification may no longer apply. In these circumstances, use the following to determine HSG according to the texture of the new surface soil, provided that significant compaction has not occurred:

HSG	Soil textures
A	Sand or gravel
B	Silt or sandy silt
C	Sandy clay or silty clay
D	Clay

If significant compaction or settlement has occurred, contact the local SCS or SCD Office for assistance in classifying the soil.

Exhibit B-2 — Hydrology: Soil Names and Hydrologic Soil Groups *(continued)*

Albrights — C
Allegheny — B
Allen (Use Gallia)
Andover — D
Ashton — B
Atkins — B
Barbour — B
Basher — B
Beech — C
Belmont — B
Benevola — C
Berks — C
Bethesda — C
Blackthorn — B
Blago — D
Blairton — C
Bodine (Use Elliber)
Braddock — B
Briery — C
Brinkerton — D
Brooke — D
Brookside — C
Buchanan — C
Calvin — C
Calvin High Base Substratum (Use Cateache)
Calvin Neutral Substratum (Use Cateache)
Caney Ville — C
Captina — C
Carbo — C
Cateache — C
Cavode — C
Cedarcreek — C
Chagrin — B
Chavies — B
Chilhowie — C
Chilo (Use Ginat)
Clarksburg — C
Clifton — B
Clymer — B
Cookport — C
Coolville — C
Corydon — D
Cotaco — C
Craigsville — B
Culleoka — B
*Dekalb — C
Dormont — C
Drall — B
Duffield —B
Duncannon — B
Dunmore — B
Dunning — D
Edgemont — B
Edom — C
Elkins — D
Elliber — A
Ernest — C
Fairpoint — C
Faywood — C
Fenwick — C
Fiveblock — C
Frankstown — B
Frederick — B
Gallia — B
Gauley — C
Gilpin — C
Ginat — D
Glenford — C
Grigsby — B
Guernsey — C
Guthrie (Use Lawrence)
Guyan — C
Guyandotte — B
Hackers — B
Hagerstown — C
Gartsells (Use Clymer)
Hazleton — B
Holly — D
Holston (Use Allegheny)
Huntington — B
Itmann — C
Janelew — C
Jefferson — B
Kanawha — B
Kaymine — C
Laidig — C
Lakin — A
Landes — B
Latham — D
Lawrence — C
Leadvale (use Ernest)
Leatherbark — C
Leetonia — C
Lehew — C
Lickdale — C
Licking — C
Lily — B
Linden — B
Lindside — C
Litz — C

*For Dekalb, use B where bedrock is fractured.

Appendix C
Storm Water Management

Introduction

The most effective storm water management criteria would require that post-development runoff from new construction projects be controlled so that pre-development runoff characteristics (quantity and quality) are maintained for all rainfall events. Practically, this ideal condition may be difficult to achieve due to the complex changes which result from urban development.

The goal in storm water management should be to maintain adequate water quality standards and to ensure that, for a predetermined frequency storm, runoff will not damage adjacent properties or exceed the capacity of receiving streams.

Criteria

Properties and waterways downstream from new development sites should be protected from erosion due to increases in the volume, velocity, and peak flow rate of storm water runoff. In many cases, state and local regulations will apply to the allowable quality and quantity of storm water runoff. Each developer or land user should become familiar with the regulations which apply to their location and take steps to comply with the applicable regulations.

In the absence of state or local regulations which apply to the quantity of runoff from a development site, the following guidelines may be used.

A. Concentrated storm water runoff leaving a development site must be discharged directly into a well-defined, natural or man-made off site receiving channel or pipe. If there is no well-defined off site receiving channel or pipe, one must be constructed to convey storm water to the nearest **adequate channel**. Newly constructed channels shall be designed as **adequate channels**.

   An **adequate channel** is defined as a natural or man-made channel or pipe which is capable of conveying the runoff from a 2-year, 24-hour storm without overtopping its banks or eroding after development of the site in question. A receiving channel may also be considered **adequate** at any point where the total contributing drainage area is at least 100 times greater than the drainage area of the development site in question; or, if it can be shown that the peak rate of runoff from the site during a 2-year storm will not be increased after development.

B. If an existing off-site receiving channel is not an **adequate channel**, one of the following options may be used.

   1. Improve the receiving channel to an **adequate** condition. Such improvements shall extend downstream until an adequate channel section is reached.

2. Develop a site design that will not cause the pre-development peak runoff rate from a 2-year, 24-hour storm to increase. Such a design may be accomplished by enhancing the infiltration capability of the site or by providing on-site storm water detention measures. The pre-development and post-development peak runoff rates may be determined by methods contained in Appendix B.

3. Provide a combination of channel improvement, storm water detention, or other measures which will accomplish the desired result.

C. All channel improvements or modifications must comply with all applicable laws and regulations. Modifications to streams should be done in accordance with the standards contained in this handbook.

D. If an option which includes storm water detention is chosen, a plan for maintenance of the detention facilities should be prepared. The plan should set forth the maintenance requirements of the facility and the party responsible for performing the maintenance.

E. Increased volumes of unconcentrated sheet flows which will cause erosion or sedimentation of adjacent property should be diverted to a stable outlet or detention facility.

Storm Water Management Practices

There are a number of practices and techniques which may be employed to manage both the quantity and quality of urban storm water runoff. Following is a summary of some runoff control practices which may be used.

A. ***Urban Impoundments***: This practice involves the construction or modification of surface water impoundments in a manner which will protect downstream areas from potential water quality degradation, flooding, and stream channel degradation due to upstream urban development. The objective is to detain storm water and release it at a controlled rate. Downstream water quality is improved through sediment removal, plant uptake of nutrients, chemical transformations, spread-out pollutant loadings and other processes. If properly constructed and maintained, a sediment basin which was used to control sediment during construction can also serve as a storm water management device.

B. ***Parking Lot Storage***: This practice involves the use of impervious parking areas as temporary impoundments during rainstorms. Parking lot drainage systems can be designed to temporarily detain storm water in special designated areas, and release it at a controlled rate. The objective is to protect downstream areas from increased flooding, stream channel degradation and/or combined sewer overflows caused by urban development. It is important that these facilities be designed to minimize potential safety hazards and inconvenience to motorists and pedestrians.

C. ***Rooftop Detention***: This practice allows storm water falling directly onto flat roof surfaces to be temporarily ponded and gradually released by incorporating controlled-flow roof drains into building designs. The purpose is to reduce adverse impacts of rooftop runoff on sewer systems and receiving streams. Rooftop detention can be incorporated into the design of most new buildings, and many existing structures also can be modified for this function.

D. ***Rooftop Runoff Disposal***: This practice encourages the disposal of rooftop runoff by systems and techniques that avoid or replace direct connections of roof drainage systems to sewer systems. The objective is to reduce the frequency of sewer overflows. Proposed alternatives to sewer connection include surface drainage, subsurface infiltrations, and runoff collection and storage.

E. ***Cistern Storage***: This practice involves the collection and storage of storm water runoff in a storage tank or chamber above or below the ground. A cistern can serve solely as a storm water detention device to protect downstream areas from flooding, stream channel degradation and/or sewer overflows, or it can be used to collect polluted runoff for later treatment. Water collected in a cistern may also be put to use for lawn watering, fire protection or other purposes.

F. ***Infiltration Pits and Trenches***: This practice involves the excavation of pits or trenches which are backfilled with sand and/or graded aggregates. Storm water runoff from impervious surfaces can be directed to these facilities for detention and infiltration. Permeable soils are a prerequisite. The potential for groundwater pollution must also be carefully evaluated.

G. ***Concrete Grid and Modular Pavement***: This practice involves the use of a special pervious paving material in low traffic areas. The pavement consists of concrete grids or other structural units placed on a pervious base such as gravel or sand. The resultant pavement provides an adequate bearing surface and yet allows a significant amount of infiltration thereby reducing runoff volume and discharge rate and improving the water quality.

H. ***Porous Asphalt Pavement***: This practice involves the use of a special asphaltic paving material which allows storm water to infiltrate at a high rate. Infiltration water is stored below the pavement in a high-void aggregate base. This practice provides for storm water detention and in some cases increases infiltration into the ground. Use of the practice can contribute to reduced sewer overflows, decreased flooding and stream channel degradation, and improved water quality.

I. ***Grassed Waterways, Filter Strips, and Seepage Areas***: This practice involves utilizing grassed surfaces to reduce runoff velocities, enhance infiltration and remove runoff contaminants, thus improving runoff quality and reducing the potential for downstream channel degradation and sediment pollution due to urban development. Concepts covered include using grass lined roadside swales instead of curb and gutter installations; using grass-lined open drainage channels instead of paved channels; using grass-covered surfaces to intercept runoff and filter out some of the contaminants; and using small shallow basins over permeable soils to capture and infiltrate runoff.

Design Aids

Many of the practices contained in this handbook can be used in a storm water management system. Methods of determining pre-development and post-development runoff are located in Appendix B. SCS Technical Release 55 contains a method of determining the amount of storage required to maintain a given peak rate of outflow.

Appendix D
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SCS reference materials, with the exception of DN-6, are available from National Technical Information Service, US Department of Commerce, 5285 Port Royal Road, Springfield, VA, 22161. TR-20, and TR-55 are available as computer programs.

Other SCS reference materials can be requested from the State Conservation Engineer, SCS, 75 High Street, Room 301, Morgantown, WV 26505.